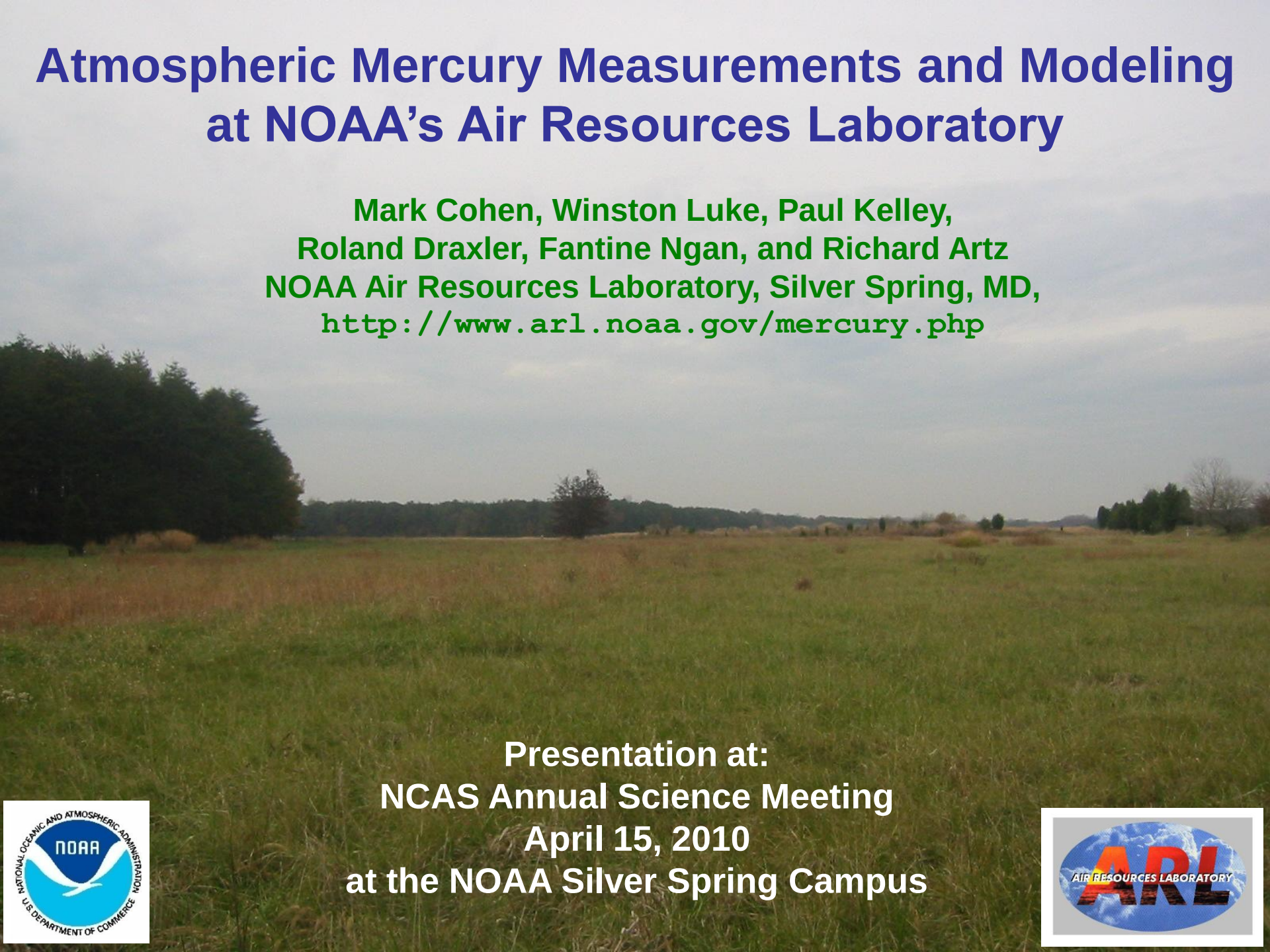
Atmospheric Mercury Measurements and Modeling at NOAA's Air Resources Laboratory

Mark Cohen, Winston Luke, Paul Kelley,
Roland Draxler, Fantine Ngan, and Richard Artz
NOAA Air Resources Laboratory, Silver Spring, MD,
http://www.arl.noaa.gov/mercury.php



Presentation at:
NCAS Annual Science Meeting
April 15, 2010
at the NOAA Silver Spring Campus

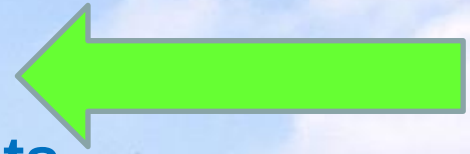
1. Measurements

A. Site Locations and Settings

B. Current Suite of Measurements

C. Intensive (this Summer)

D. Data – some examples



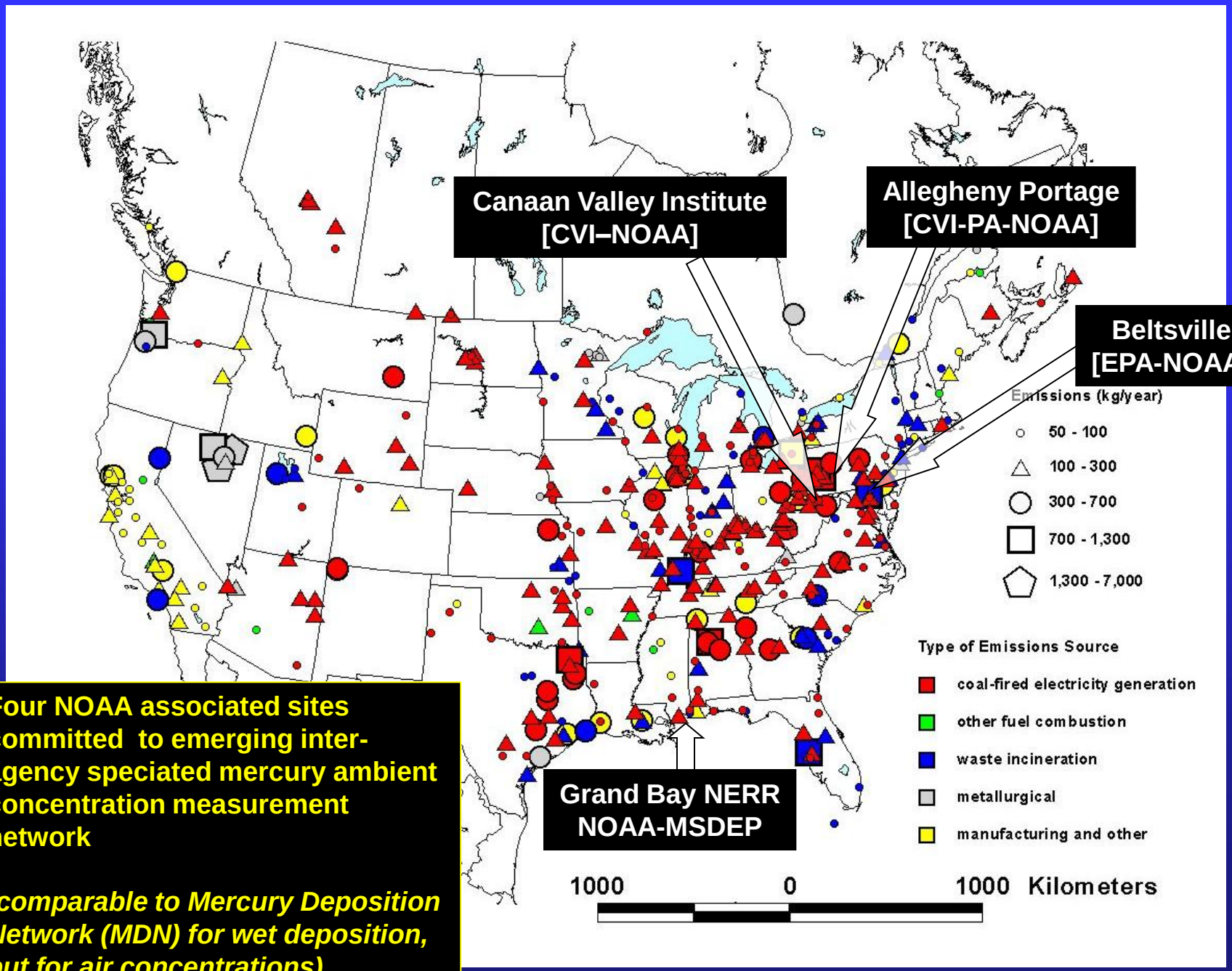
2. Modeling

A. Episodes for Model Evaluation

B. Emissions and Met Data -- Fine-Scale

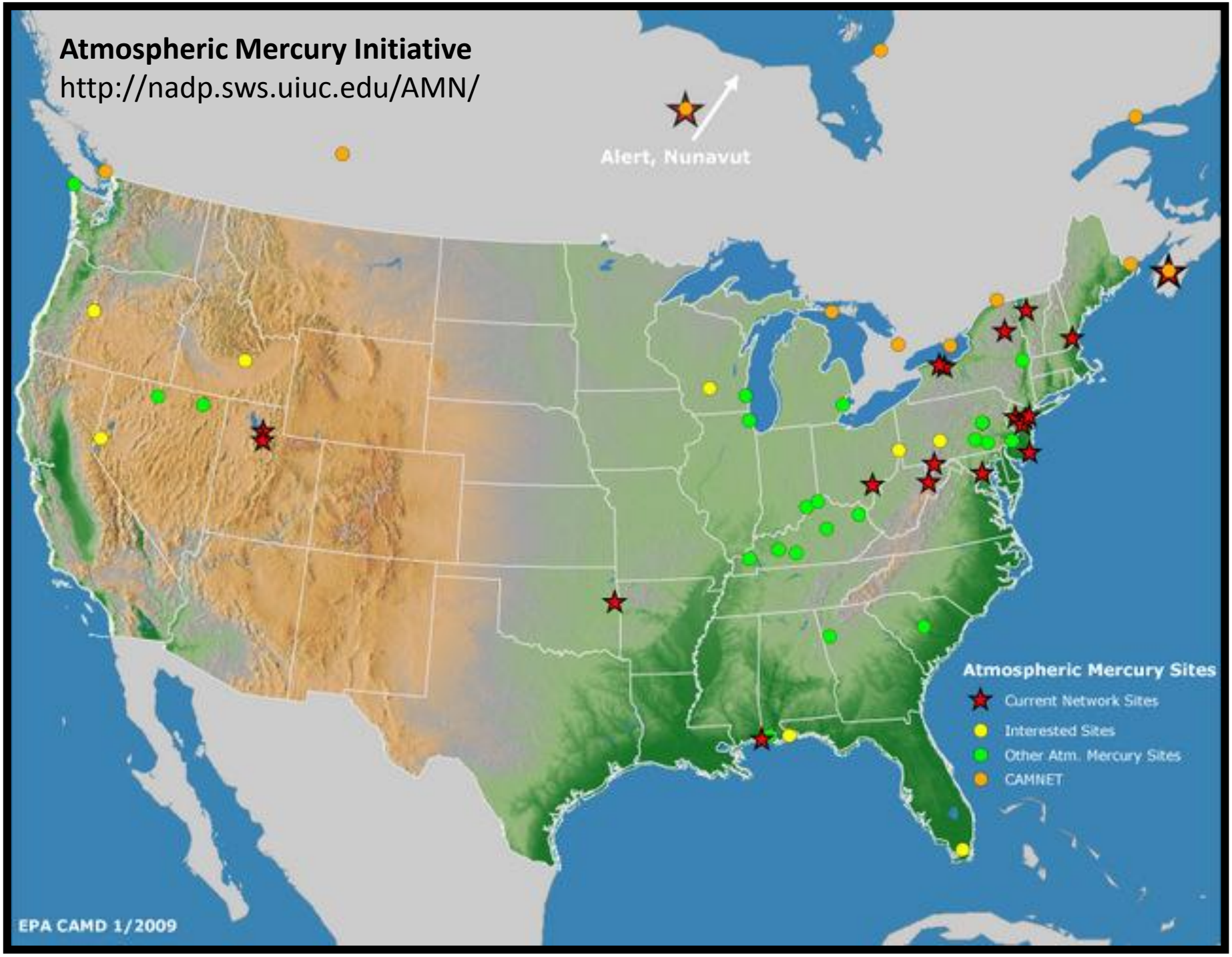
C. Evolution of the HYSPLIT-Hg Model

D. Upcoming Great Lakes Project



Four NOAA associated sites committed to emerging inter-agency speciated mercury ambient concentration measurement network

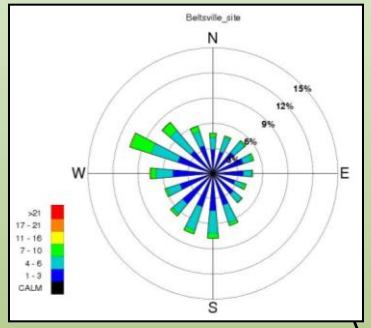
(comparable to Mercury Deposition Network (MDN) for wet deposition, but for air concentrations)


Atmospheric Mercury Initiative
http://nadp.sws.uiuc.edu/AMN/
Alert, Nunavut
Atmospheric Mercury Sites
Current Network Sites
Interested Sites
Other Atm. Mercury Sites
CAMNET
EPA CAMD 1/2009

Beltsville, Maryland

Co-located with the EPA's CASTNet site, and the Beltsville NTN and MDN sites

Beltsville monitoring site



Brunner Island

Large Incinerators:
3 medical waste,
1 MSW, 1 haz waste
(Total Hg ~ 500 kg/yr)

Harford County MSW Incin

Brandon Shores
and H.A. Wagner

100 miles
from DC

Montgomery County
MSW Incin

Dickerson

Arlington - Pentagon MSW Incin

Possum Point

Eddystone

Chalk Point

Morgantown

Bremo

0 50 100 Kilometers

N

Monitoring sites

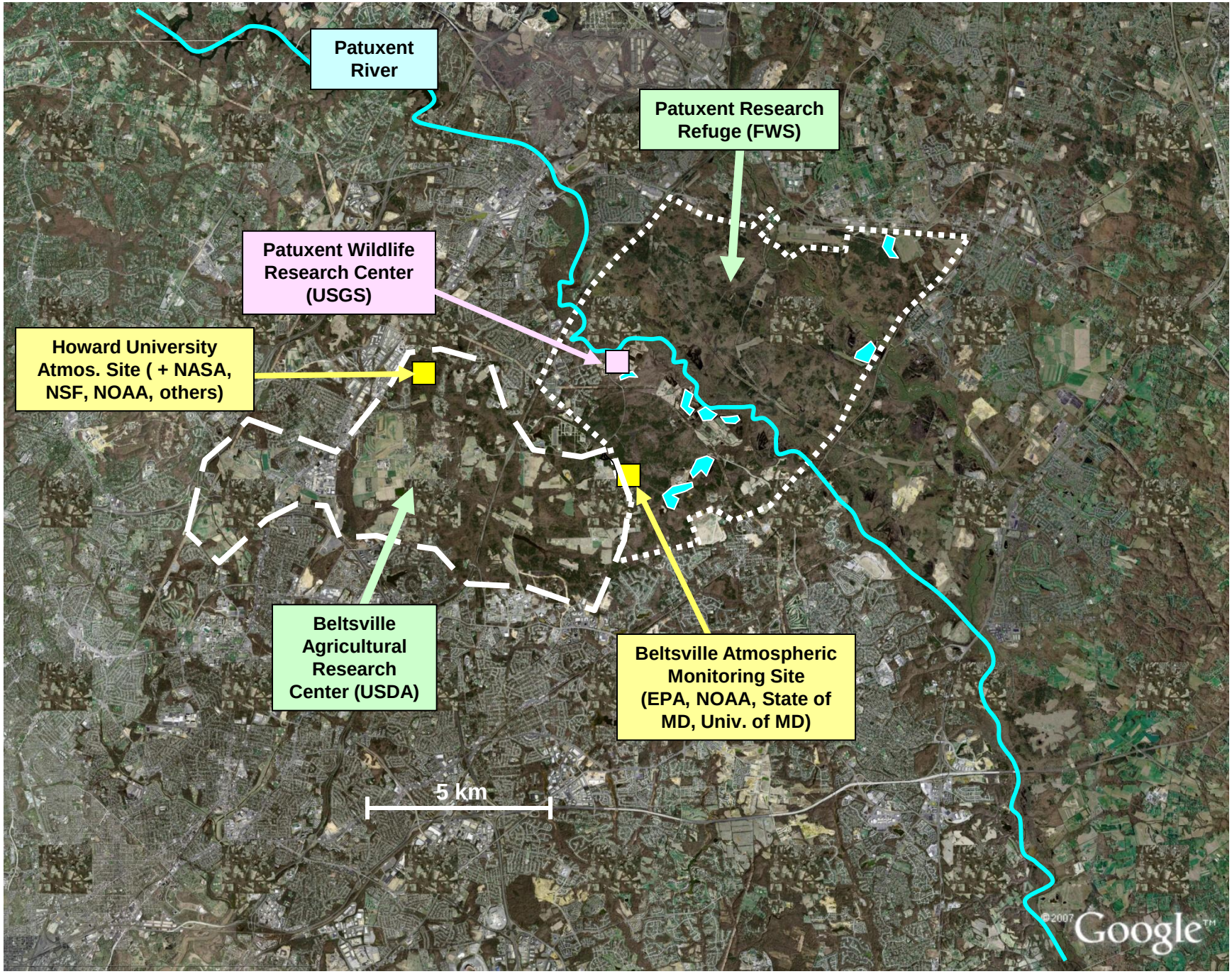
- rural AQS
- other AQS
- NADP/MDN
- CASTNet
- Hg site
- IMPROVE

Symbol color indicates type of mercury source

- coal
- incinerator
- metals
- manuf/other

Symbol size and shape indicates 1999 mercury emissions, kg/yr

- 1 - 50
- 50 - 100
- 100 - 200
- 200 – 400
- 400 - 700
- 700 – 1000
- > 1000


Patuxent River
Patuxent Research Refuge (FWS)
Patuxent Wildlife Research Center (USGS)
Howard University Atmos. Site (+ NASA, NSF, NOAA, others)
Beltsville Agricultural Research Center (USDA)
Beltsville Atmospheric Monitoring Site (EPA, NOAA, State of MD, Univ. of MD)
5 km
©2007 Google™

Atmospheric Mercury Measurement Site at Beltsville, MD

ARL's Winston Luke working with RGM and Hg(p) collectors

Precipitation measurements (left to right):
Mercury Deposition Network,
Major Ions (e.g."acid rain"),
Precipitation Amount

mercury and trace gas monitoring tower (10 meters)

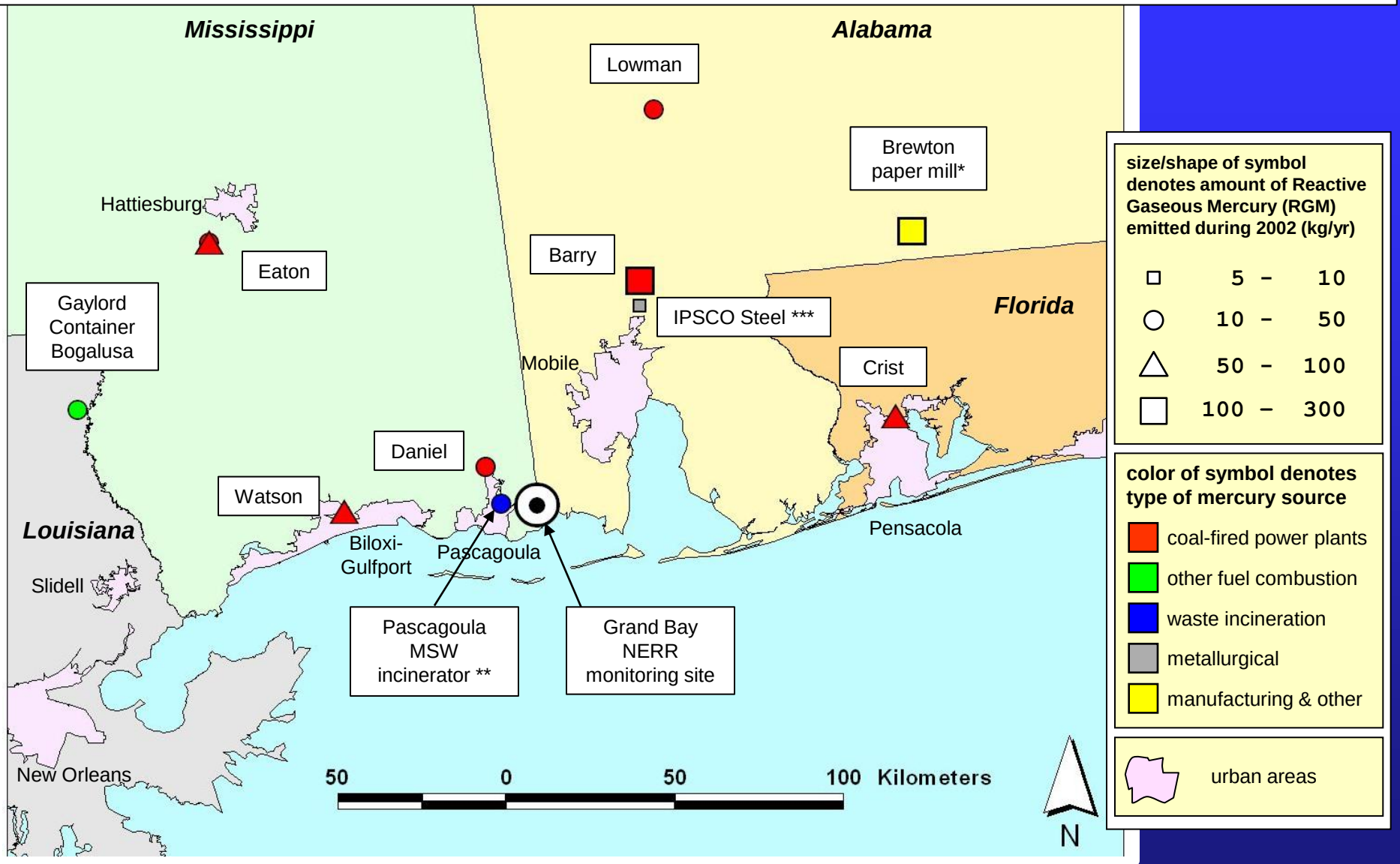
Top of tower (close-up) with two sets of RGM and Hg(p) collectors

After RGM and Hg(p) is collected, it is desorbed and analyzed inside the trailer, along with Hg(0)

Grand Bay National Estuarine Research Reserve (NERR), Mississippi

Co-located with the MS-DEQ / EPA's precipitation measurements sites (NTN, MDN, and trace metals)

Grand Bay NERR sampling site, with large point sources of Reactive Gaseous Mercury in the region, based on the EPA's 2002 National Emissions Inventory

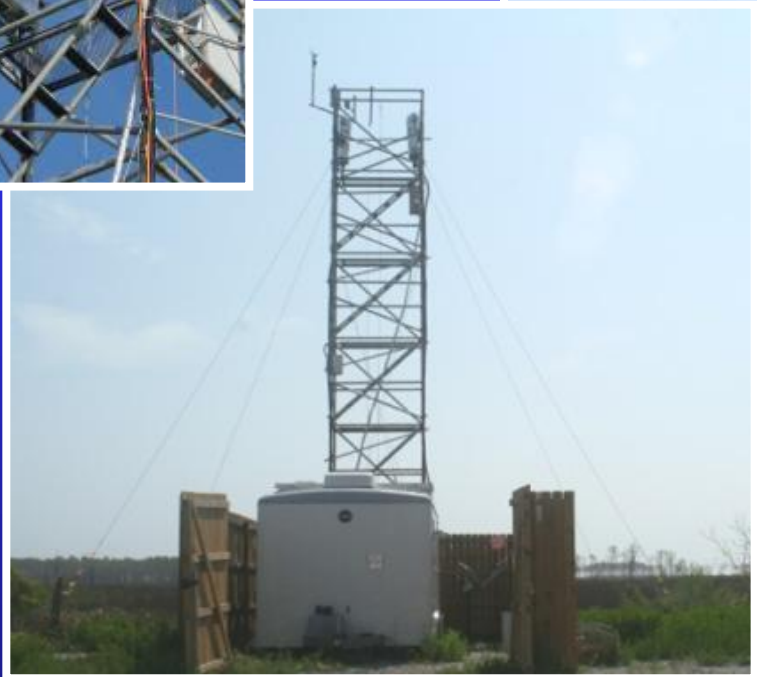


* Brewton paper mill mercury emissions included in 2002 NEI, but do not appear to be in 2000-2008 TRI

** Pascagoula MSW incinerator mercury emissions included in 2002 NEI but incineration ceased in Jan 2001

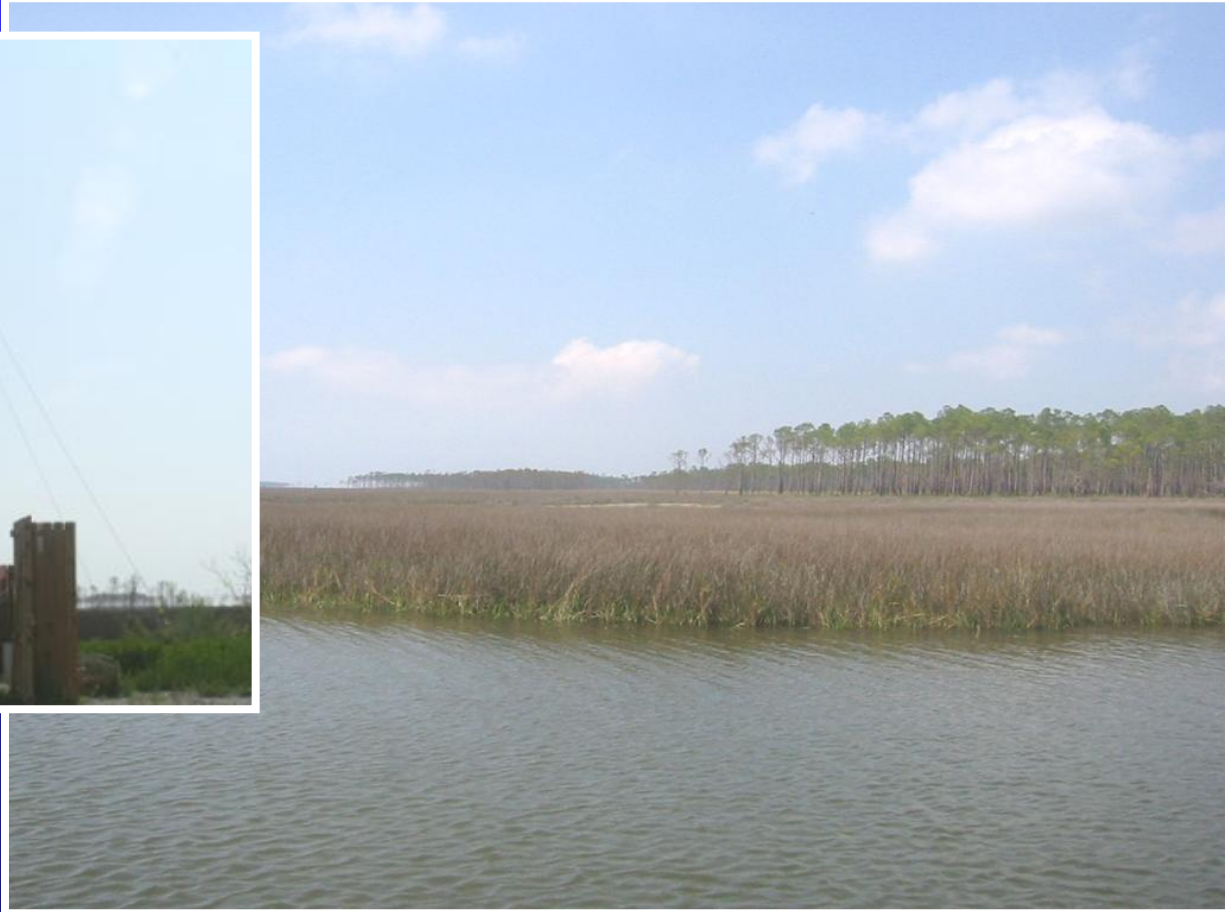
*** Ipsco Steel had significant mercury emissions in 2002 NEI, but negligible emissions reported in 2008 TRI

Current Location of Site



mercury and trace gas monitoring tower (10 meters)

view from top of the tower



“Hmmm…maybe it would work better if we have the tower go vertical?”

Winston Luke (Principal Investigator, NOAA – Air Resources Laboratory) and
Jake Walker (site operator, Grand Bay National Estuarine Research Reserve)

Current Atmospheric Measurements at the Grand Bay NERR

Elemental mercury (two instruments)	"Speciated" Atmospheric Mercury Concentrations
Fine particulate mercury (two instruments)	
Reactive gaseous mercury (two instruments)	
Sulfur dioxide	Trace gases and other measurements to help understand and interpret mercury data
Ozone	
Carbon Monoxide	
Nitrogen Oxides (NO, NOy)	
Aerosol Black Carbon	
Wind speed, Wind Direction	Meteorological Data
Temperature, Relative Humidity	
Precipitation Amount	

Instrumentation inside the trailer at the Grand Bay NERR site

Timeline of Site Activities at the Grand Bay NERR

Sept 2006: Speciated Hg, SO_2, O_3, and CO measurements begin at "inland" site

2005-2006: site selection

Jan 2008: NO/NO_y added

Aug 21 – Oct 5, 2008: site shut down due to threat of hurricanes

Jan 2010: Black Carbon added

Summer 2010: Field Intensive (being planned)

2005 | 2006 | 2007 | 2008 | 2009 | 2010

Feb 2007: Meteorological measurements added

Oct 2007: Move to "coastal" site near Pavillion; 2nd Tekran speciated Hg measurement suite added

2010: Wet Deposition measurements being added

Wet Deposition Measurements Being Added in 2010 by the Mississippi Department of Environmental Protection (Henry Folmar, Becky Comyns, others), with funding from the EPA	
Precipitation	Continuous digital measurement of precipitation amount
Major Ions pH, SO_4^{-2}, NO_3^-, PO_4^{-3}, Cl^-, NH_4^+, Ca^{+2}, Mg^{+2}, K^+, Na^+	Weekly measurements of concentrations in precipitation (NADP-NTN)
Total Mercury	Weekly measurements of concentration in precipitation (NADP-MDN)
Methyl Mercury	Monthly measurements of concentration in precipitation (composite)
Selected Trace Metals As, Cd, Cr, Cu, Pb, Ni, Se, Zn	Weekly measurements of concentrations in precipitation

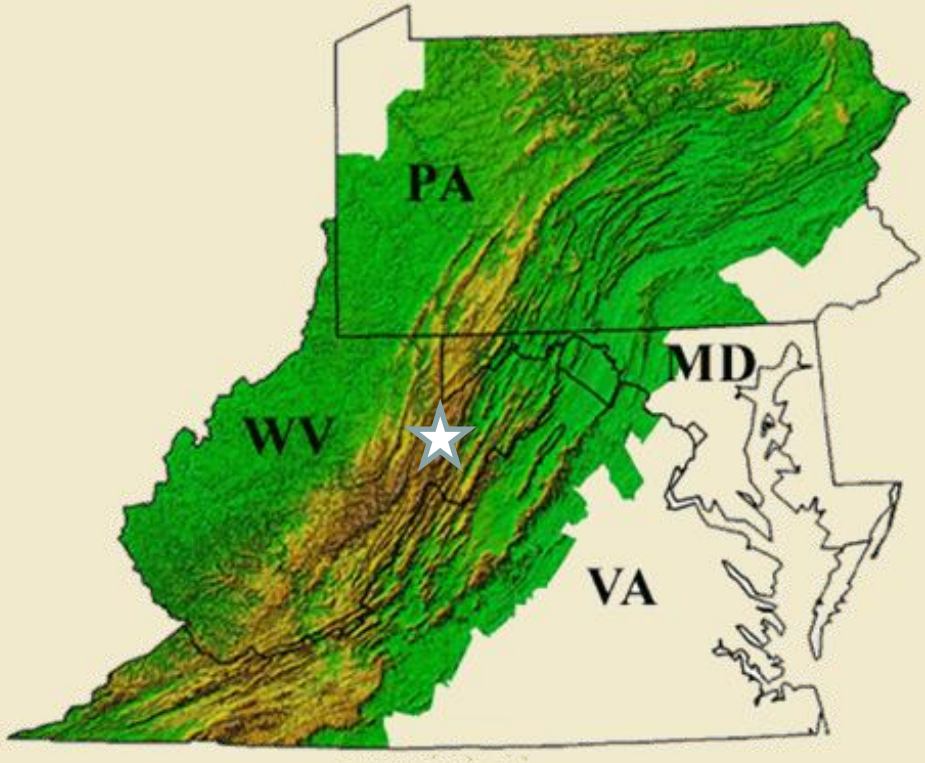
Canaan Valley, West Virginia

Operated by Steve Brooks
of the Canaan Valley Institute,
who also runs an AIRMon-Wet site,
a new MDN site, and carries out
several other Hg measurements as well

Canaan Valley Institute

CVI's Research Area is the Mid-Atlantic Highlands

NOAA performs the Mercury and Air Quality Studies



Canaan Valley non-Network Mercury Measurements

- Continuous gaseous elemental mercury surface fluxes (modified-Bowen ratio)
- Weekly total mercury snow pack and stream outflow (calibrated stream gauge)
- Monthly groundwater
- Total mercury in Throughfall (event/campaign)
- Weekly Cat-ion exchange membrane surrogate surfaces

Canaan Valley Hg Site

Ultrasonic anemometer for wind turbulence

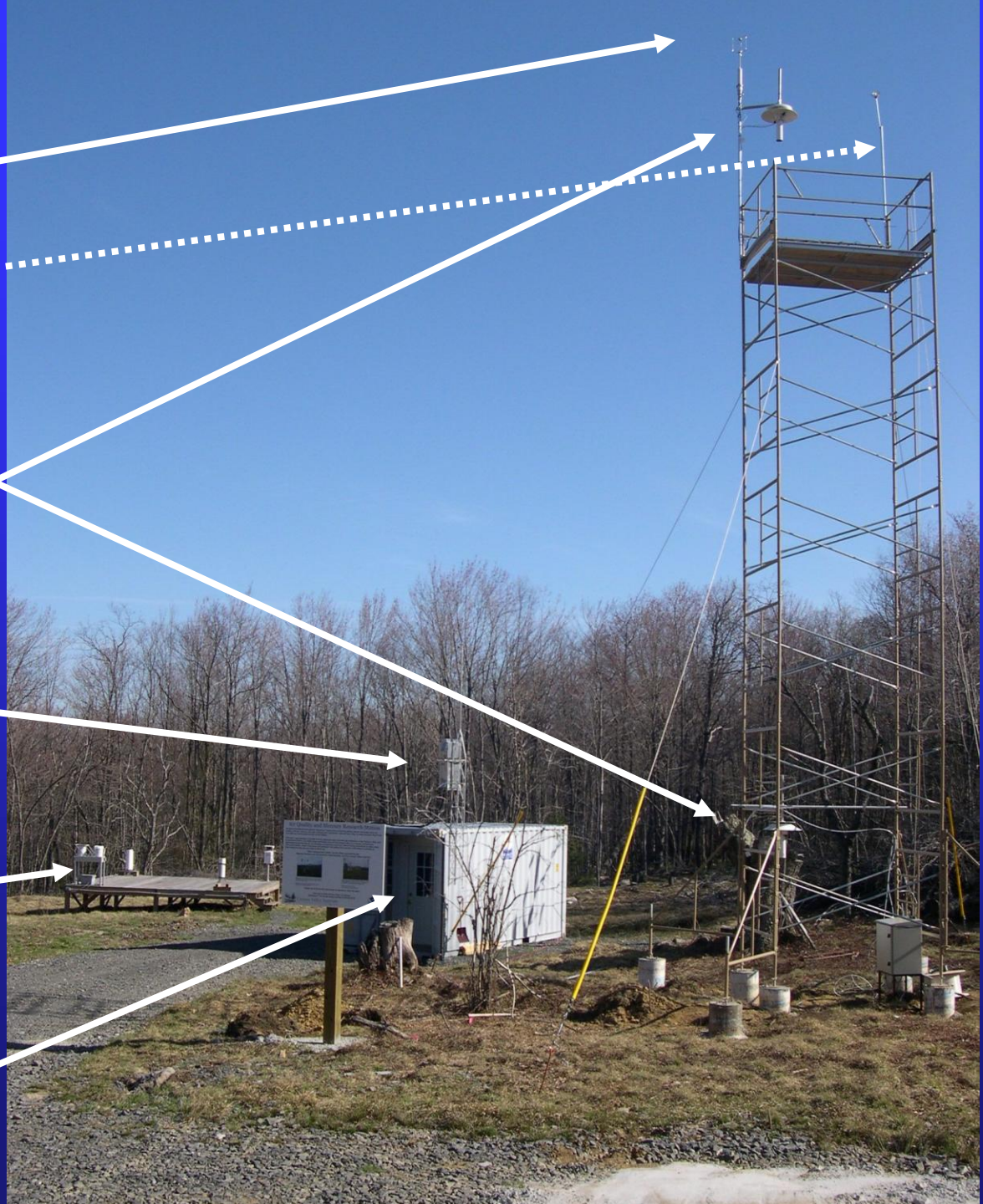
Charge dissipater for Lightning protection

Vertical profilers for mercury Air-surface exchange

Mercury chemical composition sensors

Rain and Snow collectors for Mercury and Acid Rain

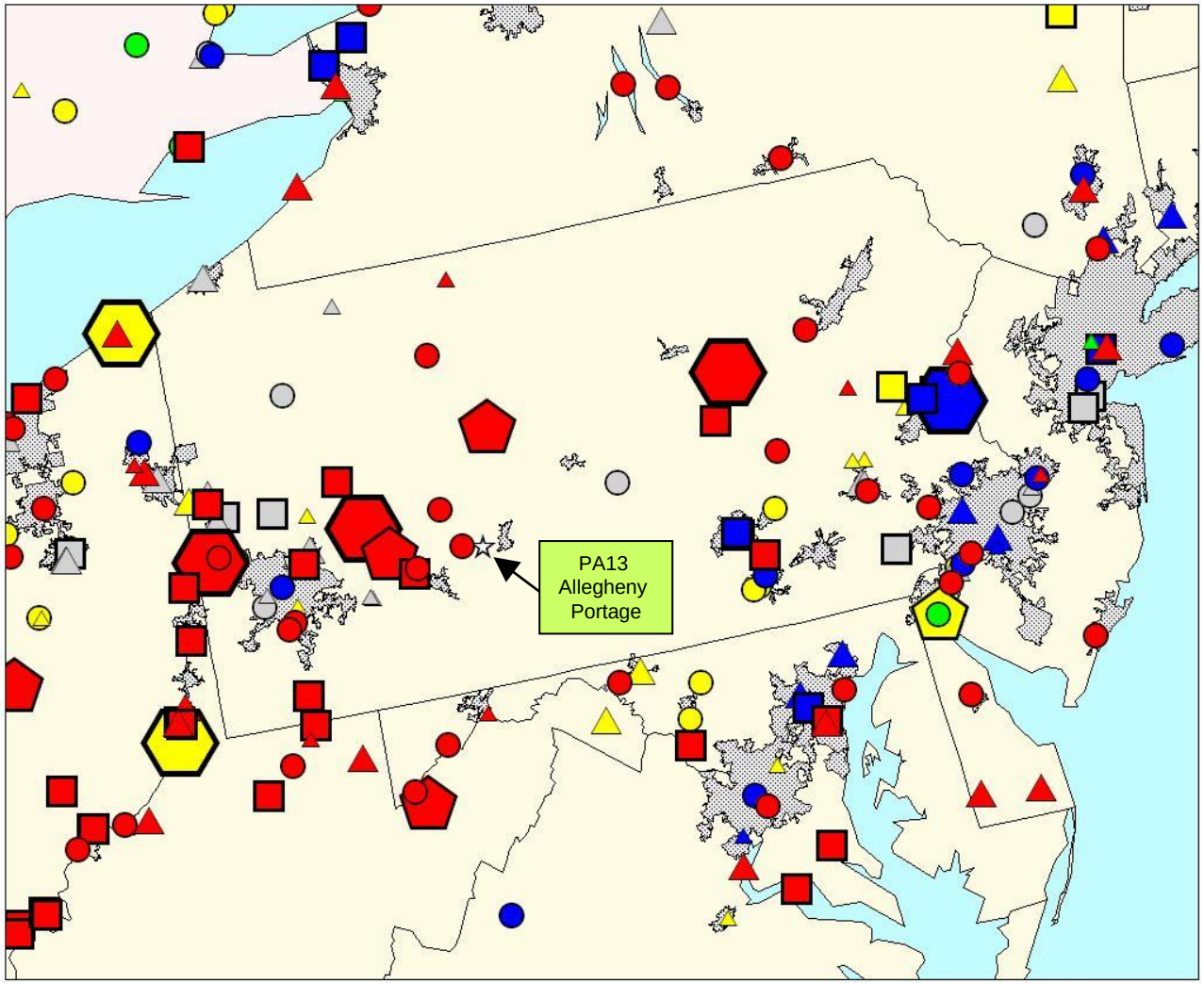
Shelter for sensors measuring mercury, ozone, carbon dioxide and other trace gases



Allegheny Portage Railroad National Historic Site, Pennsylvania

Co-located with the MS-DEQ / EPA's precipitation measurements sites (NTN, MDN, and trace metals)

Total mercury emissions from large point sources based on USEPA 2002 National Emissions Inventory (NEI)



Color of symbol indicates type of emissions source

- Coal-Fired Power Plant
- Other Fuel Combustion
- Waste Incineration
- Metallurgical
- Manufacturing

Size/shape of symbol indicates amount of mercury emitted

- 5-10
- 10-50
- 50-100
- 100-300
- 300-500
- 500-1000
- 1000-3000

☆ Pa13 (Allegheny Portage)

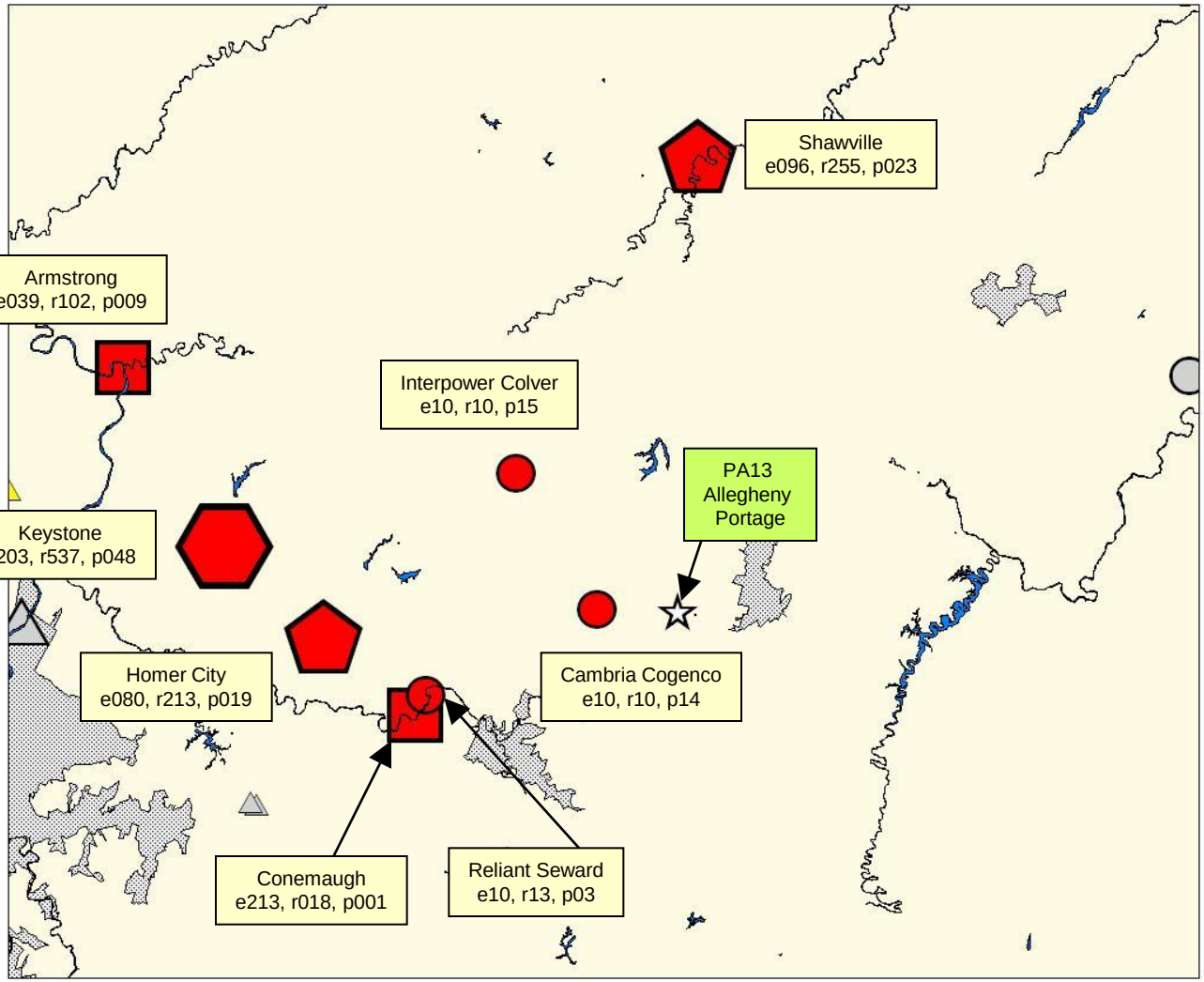
Urbanized areas

100 0 100 200 Kilometers

N

Total mercury emissions from large point sources based on USEPA 2002 National Emissions Inventory (NEI)

Numbers in facility labels are kg/yr emissions of elemental, reactive gaseous, and particulate mercury, respectively



Color of symbol indicates type of emissions source

- Coal-Fired Power Plant
- Other Fuel Combustion
- Waste Incineration
- Metallurgical
- Manufacturing

Size/shape of symbol indicates amount of mercury emitted

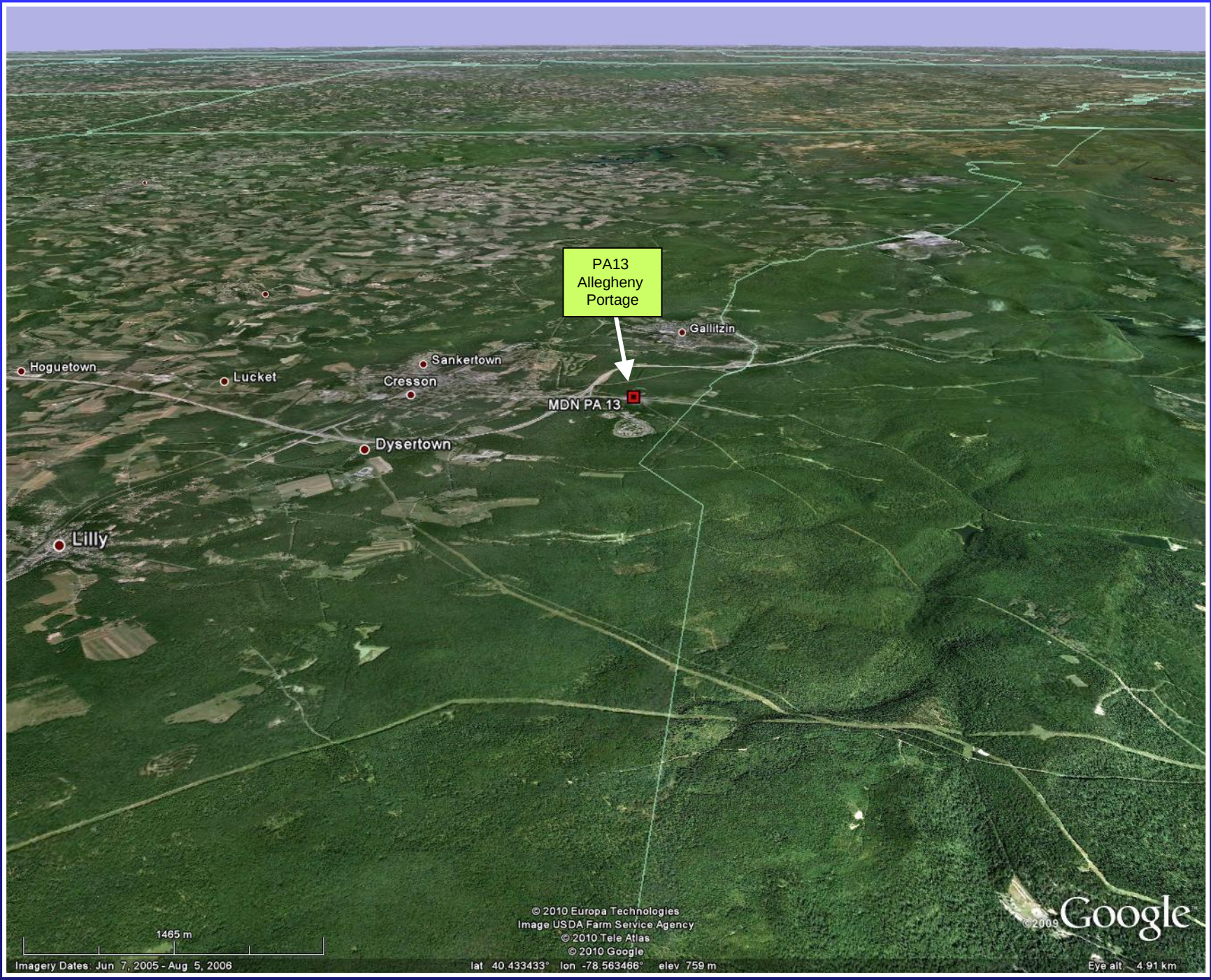
- 5-10
- 10-50
- 50-100
- 100-300
- 300-500
- 500-1000
- 1000-3000

☆ Pa13 (Allegheny Portage)

Urbanized areas

25 0 25 50 Kilometers

N


PA13
Allegheny
Portage
Gallitzin
Hoguetown
Lucket
Sankertown
Cresson
MDN PA 13
Dysertown
Lilly
© 2010 Europa Technologies
Image USDA Farm Service Agency
© 2010 Tele Atlas
© 2010 Google
1465 m
Imagery Dates: Jun 7, 2005 - Aug 5, 2006
lat 40.433433° lon -78.563466° elev 759 m
Eye alt 4.91 km
© 2009 Google

National Atmospheric Deposition Program

NADP/MDN Monitoring Location PA13

Station	Allegheny Portage Railroad National Historic Site (PA13)
Location	Cambria County, Pennsylvania
Dates of Operation	1/7/1997 - Present
Latitude	40.457
Longitude	-78.56
Elevation	739 meters
USGS 1:24000 Map Name	Cresson, 1981
Operating Agency	Allegheny Portage Railroad National Historic Site
Sponsoring Agency	Pennsylvania Department of Environmental Protection

1. Measurements

A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

2. Modeling

A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

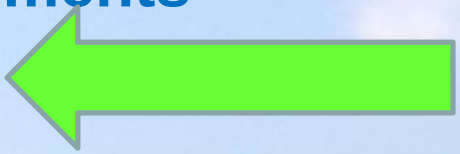
Summary of NOAA ARL Mercury Measurement Sites

● NOAA-led measurement
● Co-located measurement

Site	Collaborators / Co-locators	Ambient Air Measurements						Precipitation			Dry Deposition		Other
		Mercury Speciation	SO_2	O_3	NO/NO_y	CO	Carbon black	Major Ions (NTN)	Mercury (MDN)	Trace Metals	Surrogate Surface	Throughfall	Meteorology
Beltsville (MD)	▪ ***PI = Winston Luke (NOAA)*** ▪ EPA Clean Air Markets Division ▪ Univ of Maryland ▪ Maryland DNR ▪ MACTEC ▪ USGS	●	●	●	●	●		●	●			●	●
Grand Bay (MS)	▪ ***PI = Winston Luke (NOAA)*** ▪ Grand Bay NERR ▪ MS Dept Envr Quality ▪ U.S. EPA ▪ U.S. Fish & Wildlife Agency	●	●	●	●	●	●	●	●	●			●
Canaan Valley (WV)	▪ **PI = Steve Brooks(CVI/NOAA** ▪ Canaan Valley Institute ▪ Univ Md Frostburg Appalachian Lab ▪ USGS	●		●				●	●		●	●	●
Allegheny Portage (PA)	▪ ***PI = Steve Brooks (CVI/NOAA)*** ▪ Canaan Valley Institute ▪ Pennsylvania DEP ▪ National Park Service	●						●	●				

1. Measurements

A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples



2. Modeling

A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

Plans for Atmospheric Field Intensive, July-Aug 2010 at the Grand Bay NERR

Ground-Based Measurements	
(ongoing) speciated mercury, trace gas, black carbon, and meteorological measurements	• Winston Luke and Paul Kelley (NOAA ARL) • Jake Walker (Grand Bay NERR)
(ongoing) wet deposition: major ions, mercury, methylmercury, metals Will try to switch to event-based during intensive	• Mississippi State Dept of Env Protection/EPA • Jake Walker (Grand Bay NERR)
ambient concentrations of BrO at the surface via Chemical Ionization Mass Spectrometry (possibly other Br compounds, e.g., Br2, BrCl, and HOBr	• Greg Huey (Georgia Tech)
isotopic mercury analysis of event-based precipitation and aerosols	• Bill Landing, Flip Froelich (Florida State Univ)
trace metal analysis of size-segregated aerosol Spring 2010 and possibly during intensive	• Mark Engle (USGS)
Aircraft and Above Surface Measurements	
aircraft flights measuring concentrations of Hg^0 (Tekran), total and "speciated" RGM (coated/uncoated denuders), O_3, SO_2, and particle count	•Stephen Corda, John Muratore, & colleagues (Univ. of Tennessee Space Institute – UTSI) • Hynes and Swartzendruber (Univ of Miami) • Luke and Kelley (NOAA ARL)
vertical distribution of O_3 and met data above the site (ozonesondes)	• Luke and Kelley (NOAA ARL) • Jake Walker (Grand Bay NERR)

Details are still being worked out…

1. Measurements

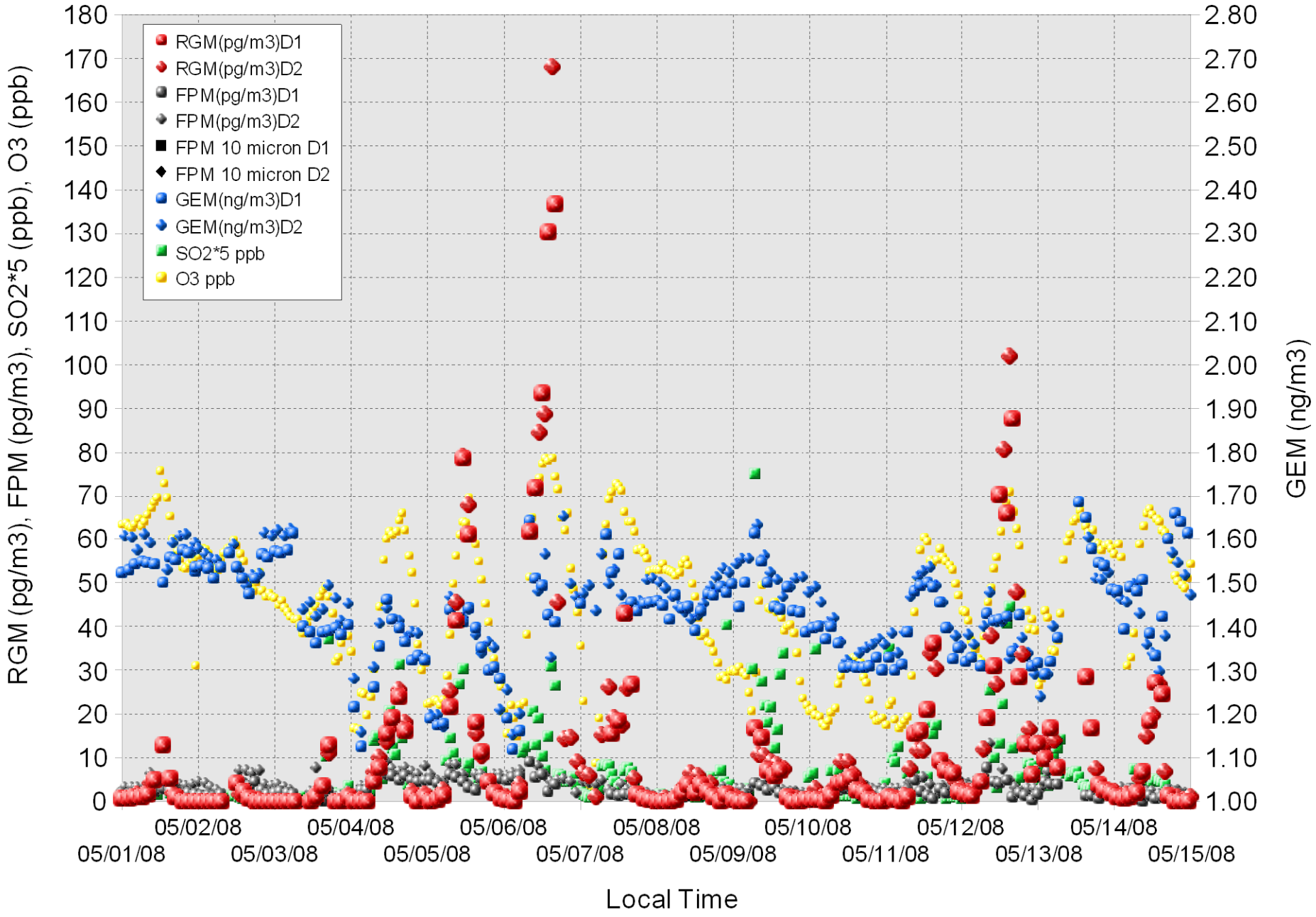
A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

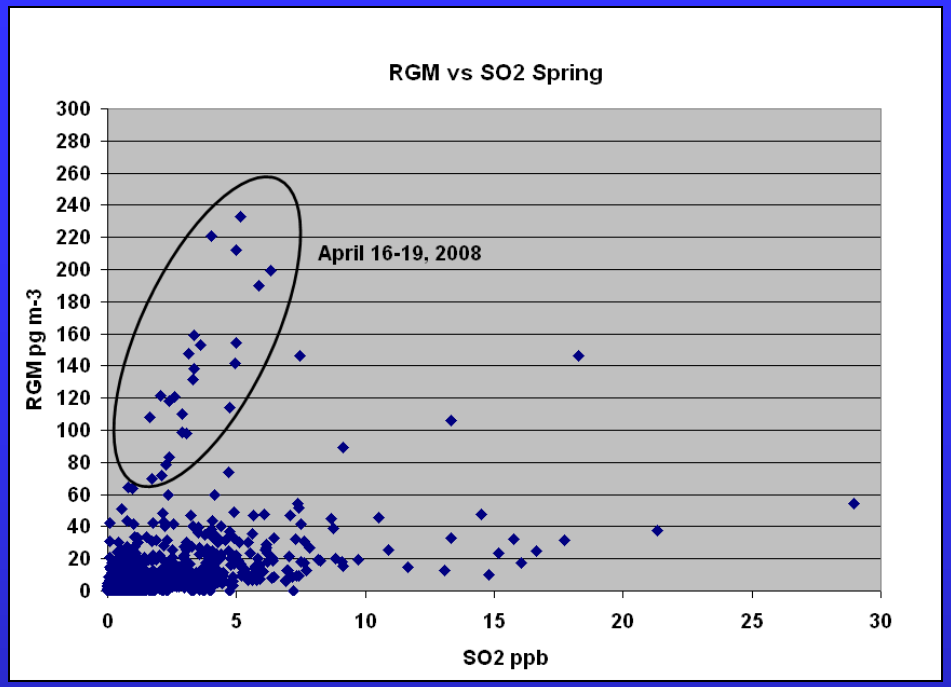
2. Modeling

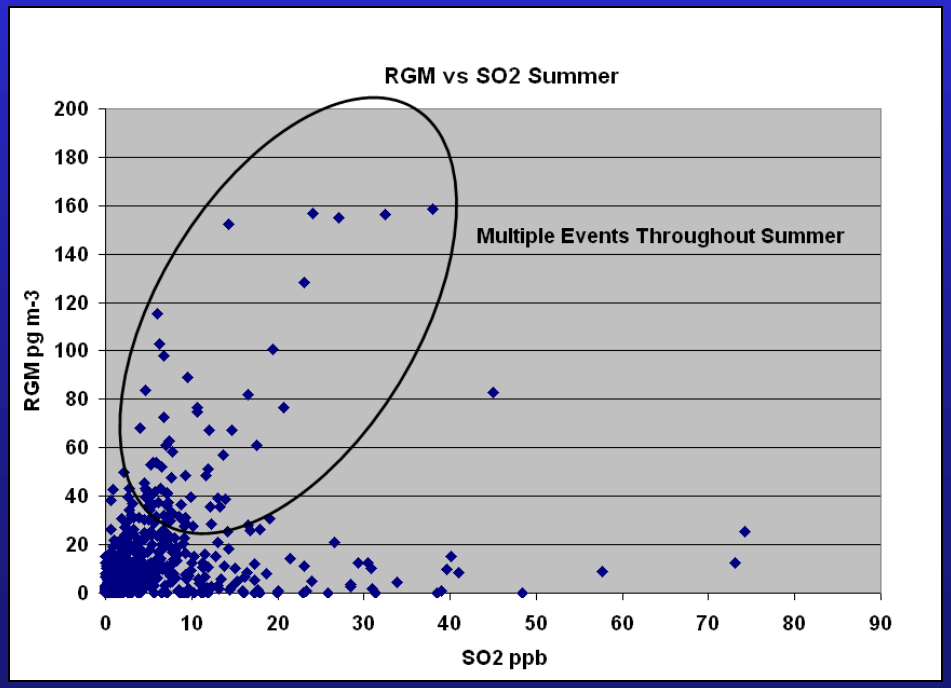
A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

Speciated Atmospheric Mercury and Selected Trace Gas Concentration Measurements at Grand Bay NERR

Courtesy of Winston Luke and Paul Kelley (NOAA ARL) and Jake Walker (Grand Bay NERR) (Preliminary Values)

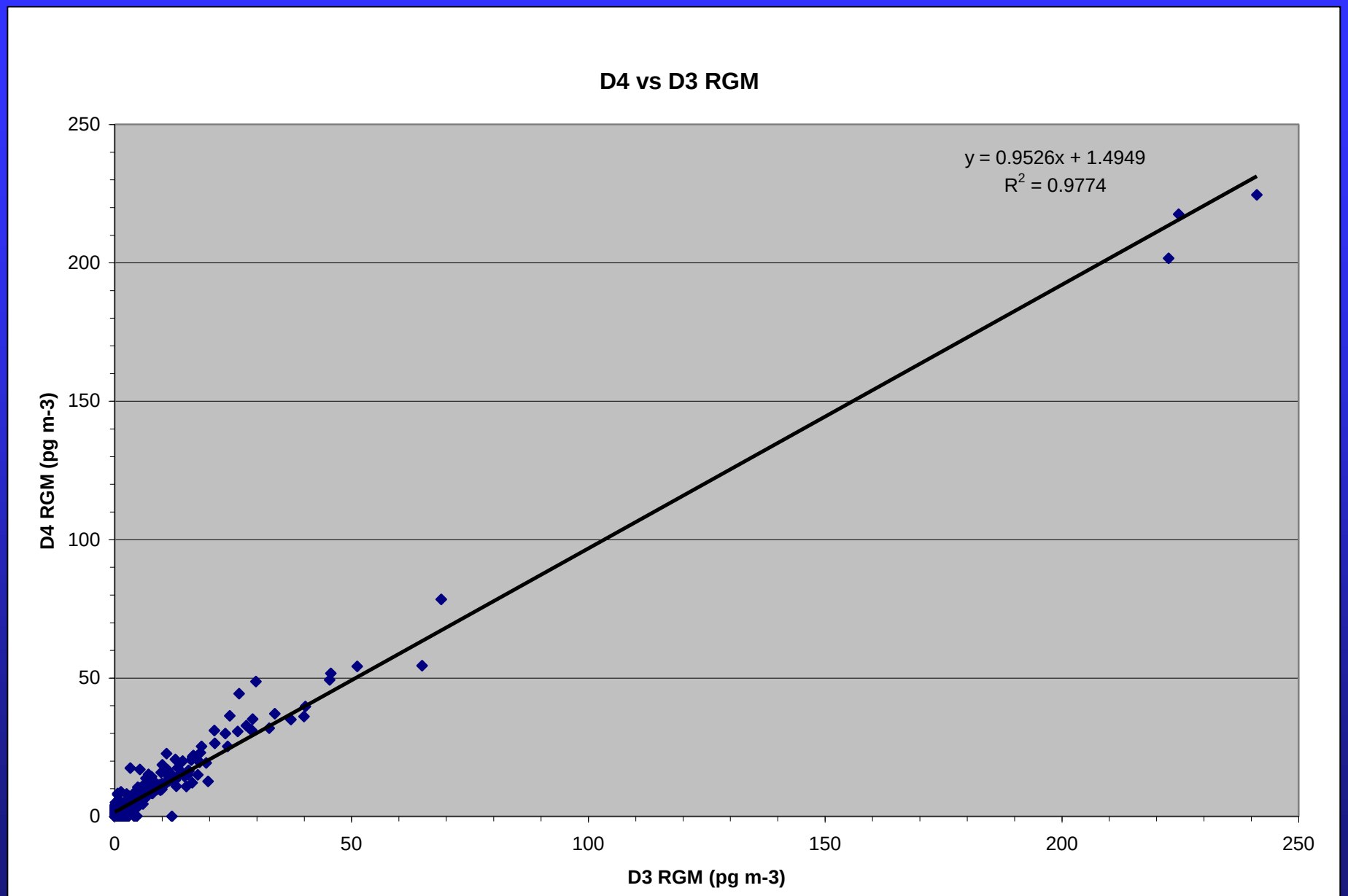


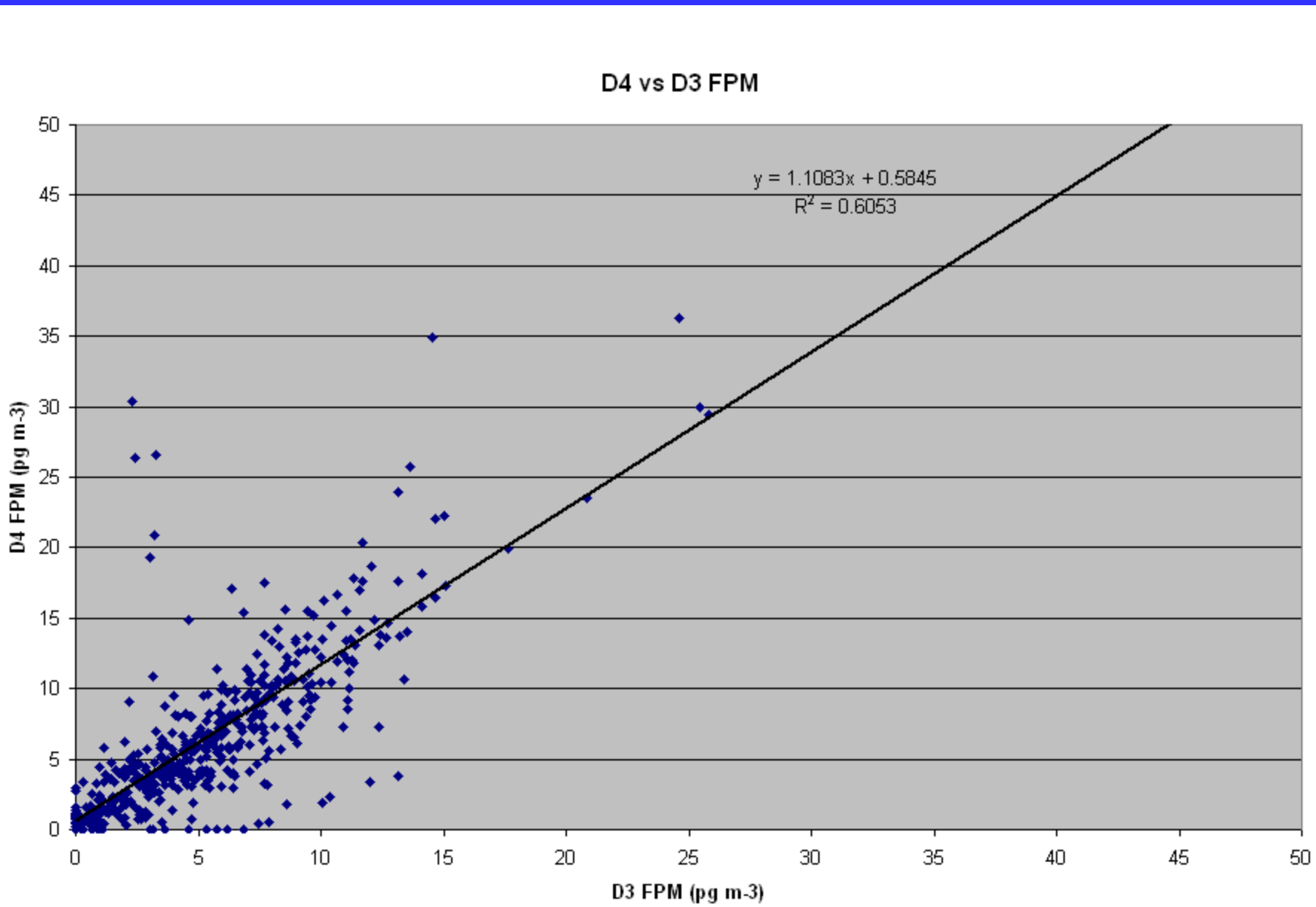


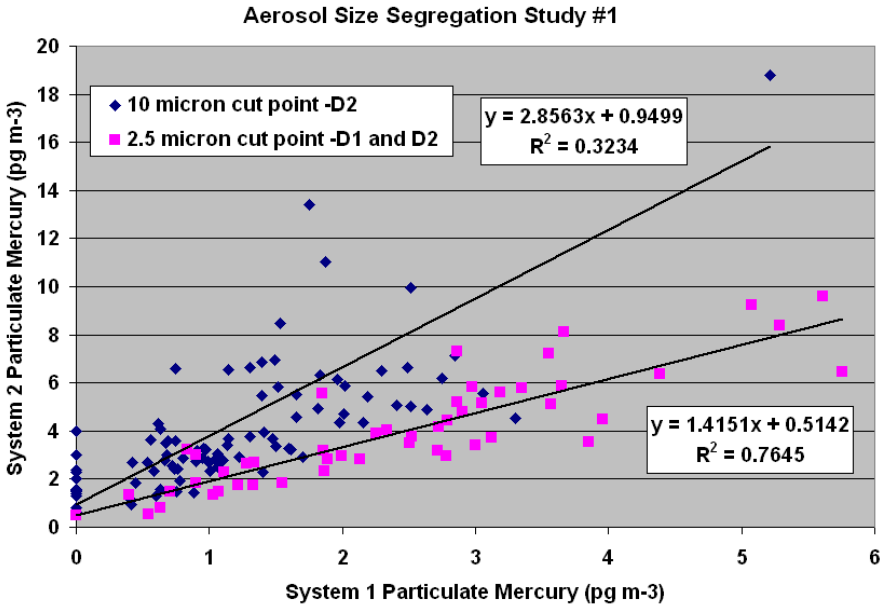


Beltsville site is impacted by a variety of local-regional sources with unique emissions characteristics.

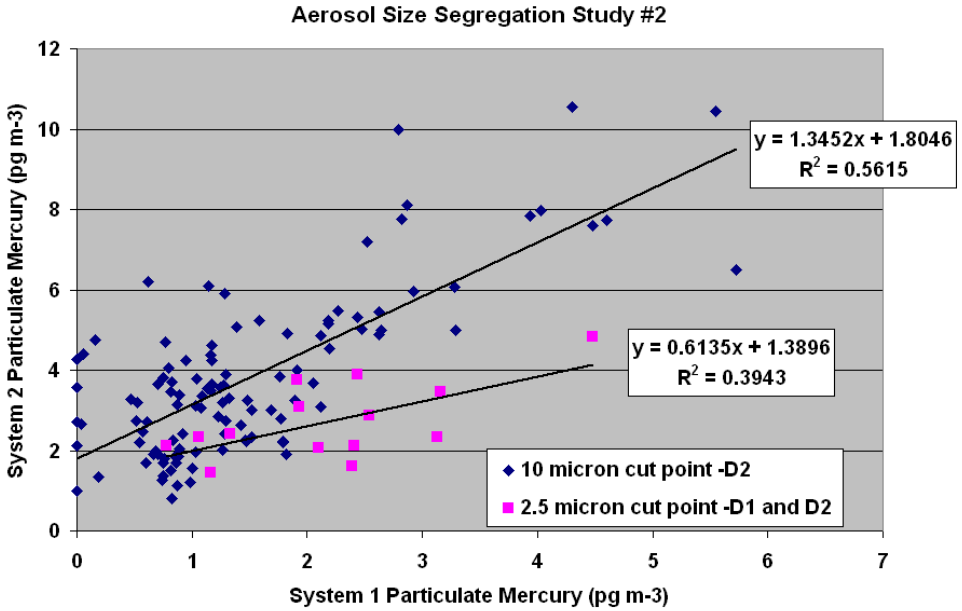
Coupled chemical-meteorological analysis will yield important insights into mercury emissions, transport, transformation, and removal at the site.


D4 vs D3 RGM
y = 0.9526x + 1.4949
R2 = 0.9774
D4 RGM (pg m-3)
D3 RGM (pg m-3)
0
50
100
150
200
250


D4 vs D3 FPM
y = 1.1083x + 0.5845
R2 = 0.6053
D4 FPM (pg m-3)
D3 FPM (pg m-3)
0
5
10
15
20
25
30
35
40
45
50



Two systems were configured identically (pink), then System 2 was fitted with a 10-micron cut point elutriator (blue) over the course of several days.



Results suggest that there may be as much mercury in the coarse (sea salt) aerosol fraction as in the fine fraction.

Studies will be repeated periodically at the site.

1. Measurements

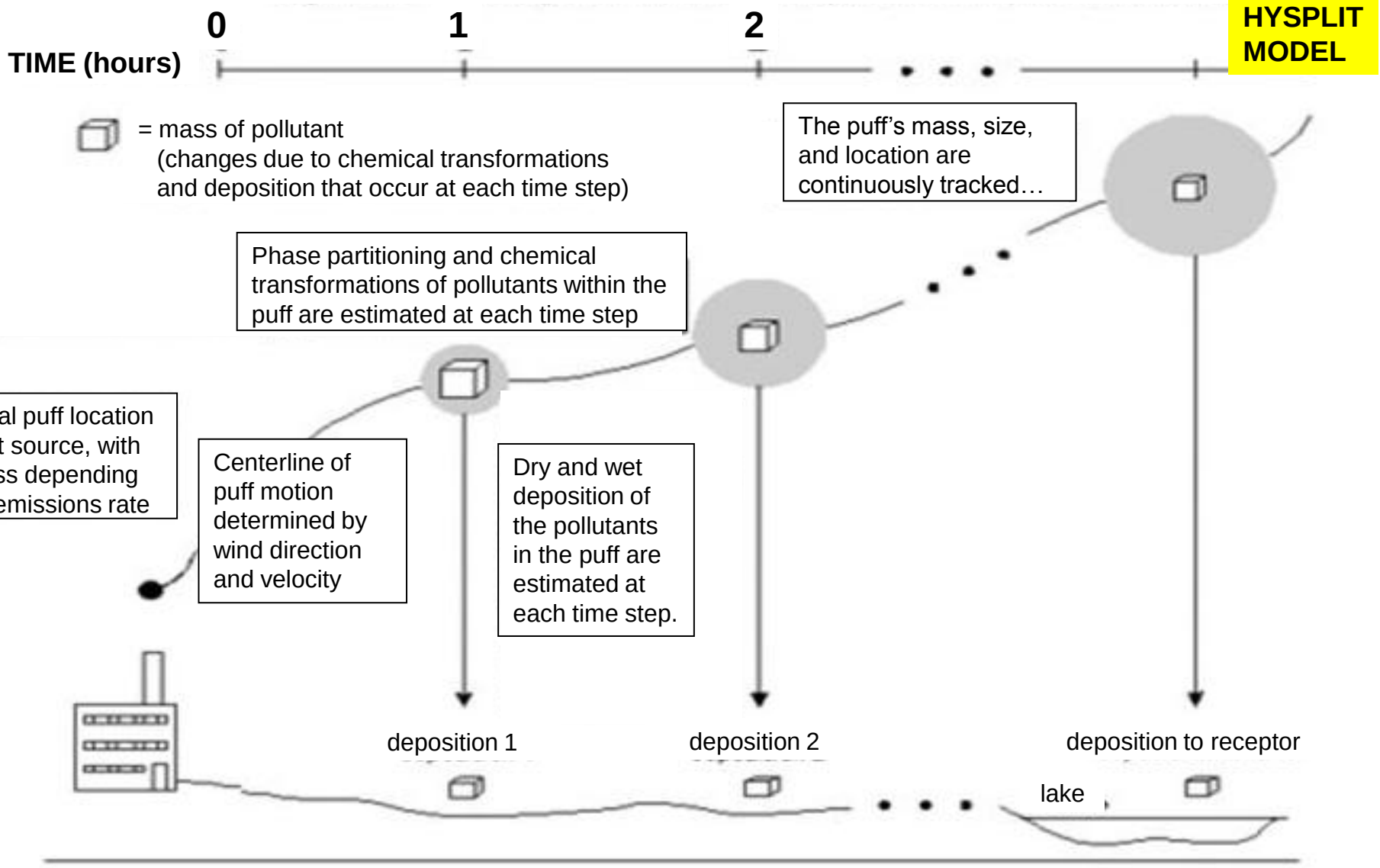
A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

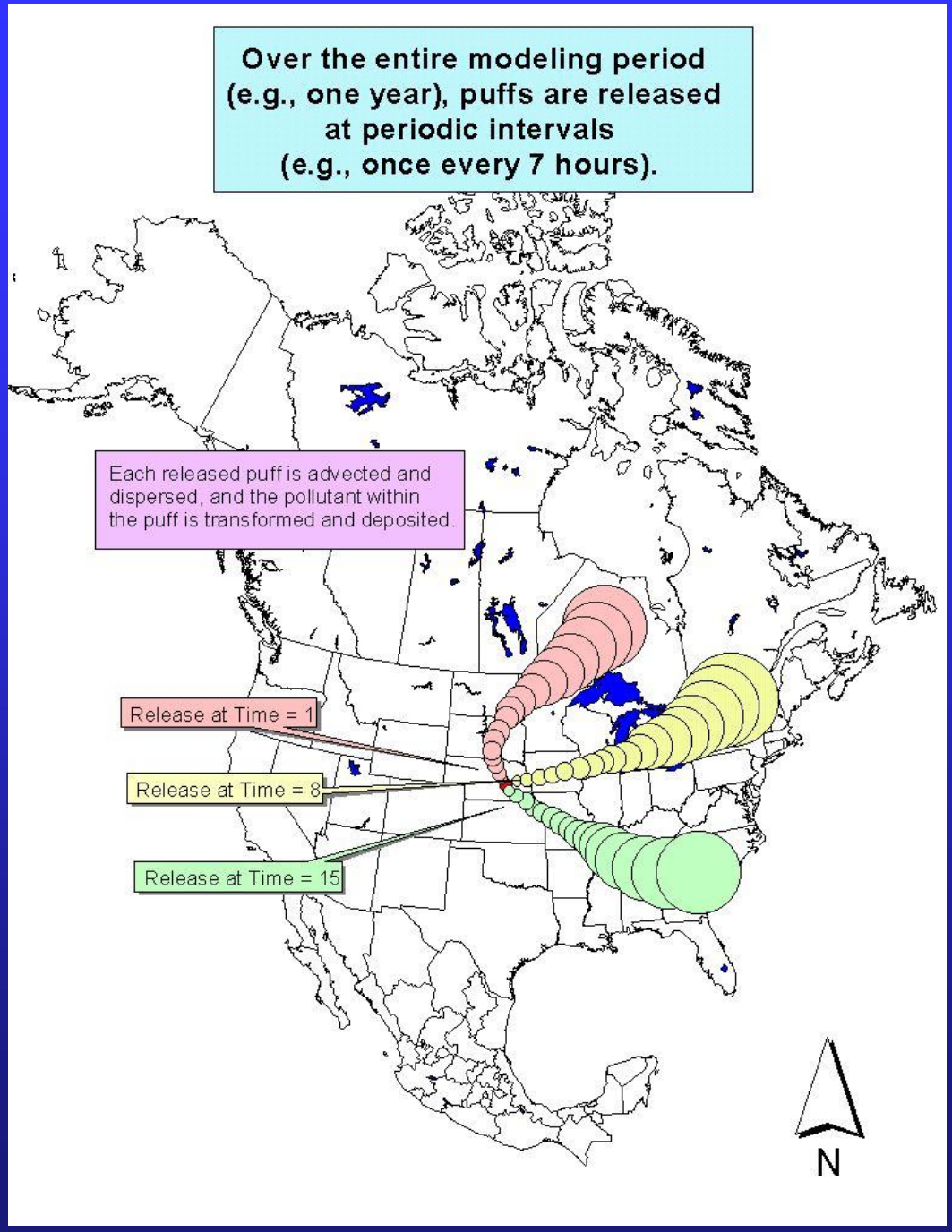
2. Modeling

A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

Lagrangian Puff Atmospheric Fate and Transport Model

NOAA HYSPLIT MODEL




Over the entire modeling period (e.g., one year), puffs are released at periodic intervals (e.g., once every 7 hours).
Each released puff is advected and dispersed, and the pollutant within the puff is transformed and deposited.
Release at Time = 1
Release at Time = 8
Release at Time = 15
N

(Evolving) Atmospheric Chemical Reaction Scheme for Mercury

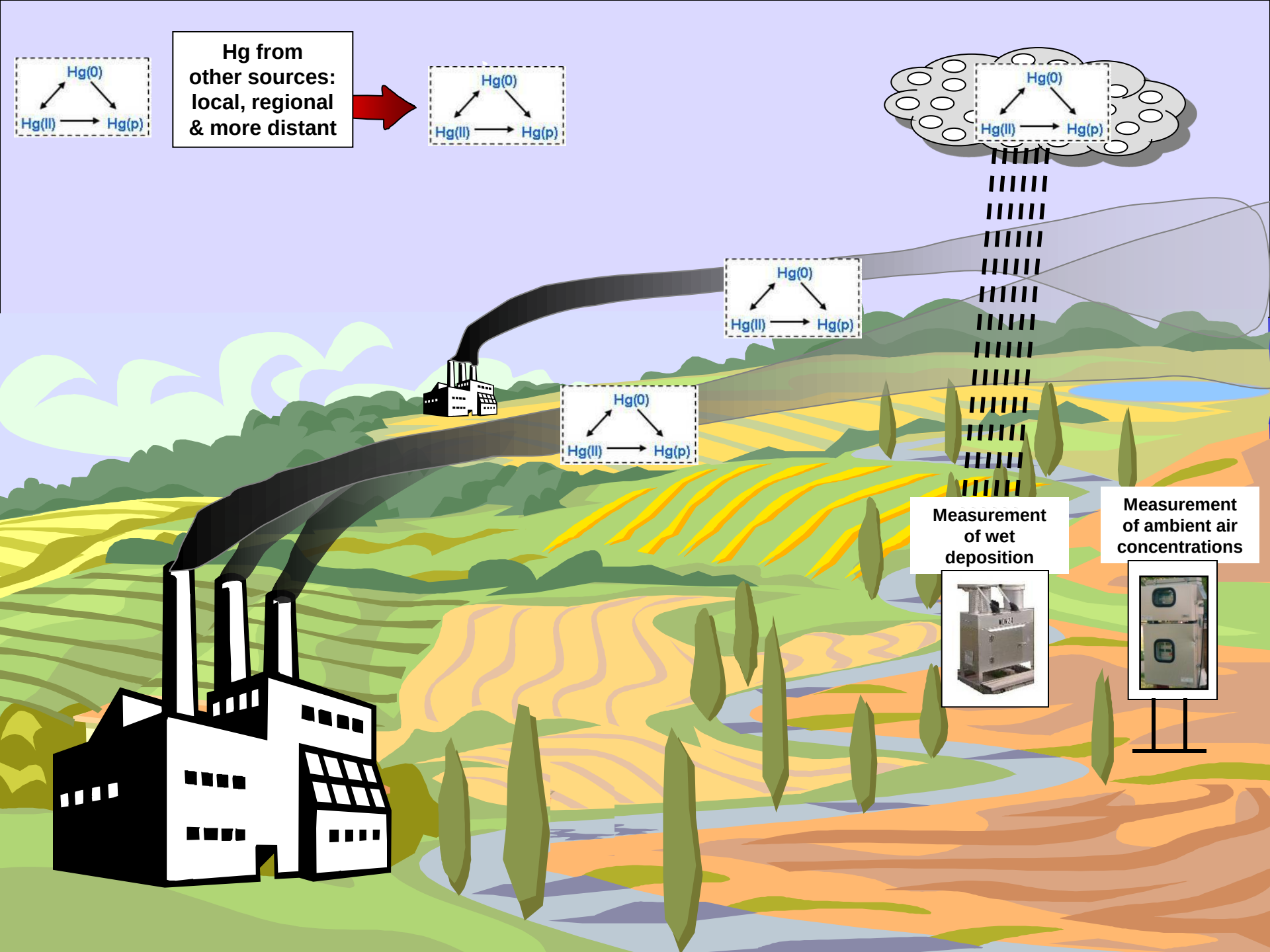
	Reaction	Rate	Units	Reference
	GAS PHASE REACTIONS			
?	$Hg^0 + O_3 \rightarrow Hg(p)$	3.0E-20	cm^3/molec-sec	Hall (1995)
	$Hg^0 + HCl \rightarrow HgCl_2$	1.0E-19	cm^3/molec-sec	Hall and Bloom (1993)
	$Hg^0 + H_2O_2 \rightarrow Hg(p)$	8.5E-19	cm^3/molec-sec	Tokos et al. (1998) (upper limit based on experiments)
	$Hg^0 + Cl_2 \rightarrow HgCl_2$	4.0E-18	cm^3/molec-sec	Calhoun and Prestbo (2001)
?	$Hg^0 + OH \rightarrow Hg(p)$	8.7E-14	cm^3/molec-sec	Sommar et al. (2001)
new	$Hg^0 + Br \rightarrow HgBr_2$			
	AQUEOUS PHASE REACTIONS			
	$Hg^0 + O_3 \rightarrow Hg^{+2}$	4.7E+7	$(molar\text{-}sec)^{-1}$	Munthe (1992)
	$Hg^0 + OH \rightarrow Hg^{+2}$	2.0E+9	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1997)
	$HgSO_3 \rightarrow Hg^0$	$T*e^{((31.971*T)-12595.0)/T)}$ sec^{-1} [T = temperature (K)]		Van Loon et al. (2002)
?	$Hg(II) + HO_2 \rightarrow Hg^0$	~ 0	$(molar\text{-}sec)^{-1}$	Gardfeldt & Jonnson (2003)
	$Hg^0 + HOCl \rightarrow Hg^{+2}$	2.1E+6	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1998)
	$Hg^0 + OCl^{-1} \rightarrow Hg^{+2}$	2.0E+6	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1998)
	$Hg(II) \leftrightarrow Hg(II)_{(soot)}$	9.0E+2	liters/gram; t = 1/hour	**eqlbrm:** Seigneur et al. (1998) **rate:** Bullock & Brehme (2002).
	$Hg^{+2} + hv \rightarrow Hg^0$	6.0E-7	$(sec)^{-1}$ (maximum)	Xiao et al. (1994); Bullock and Brehme (2002)

1. Measurements

A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

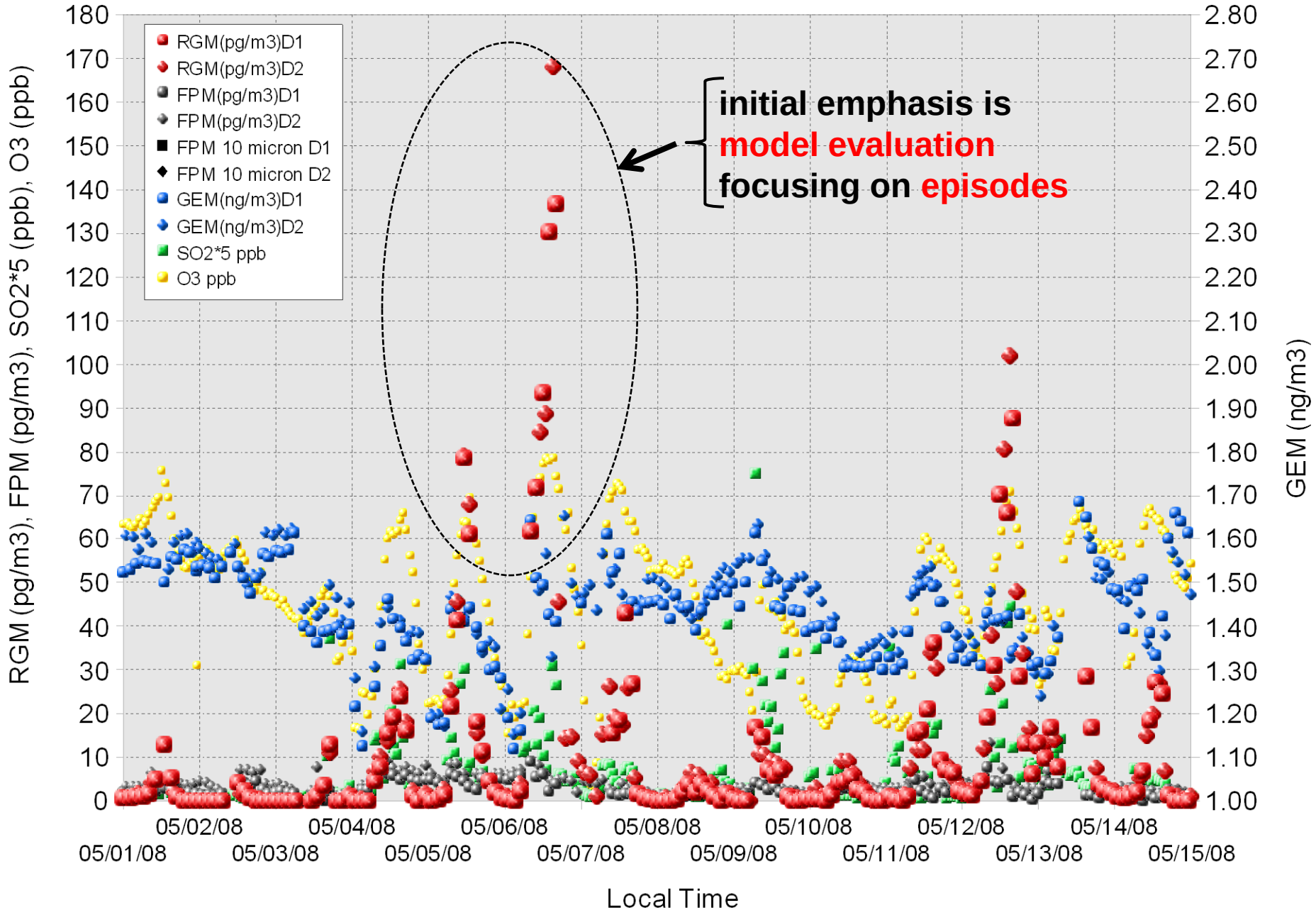
2. Modeling

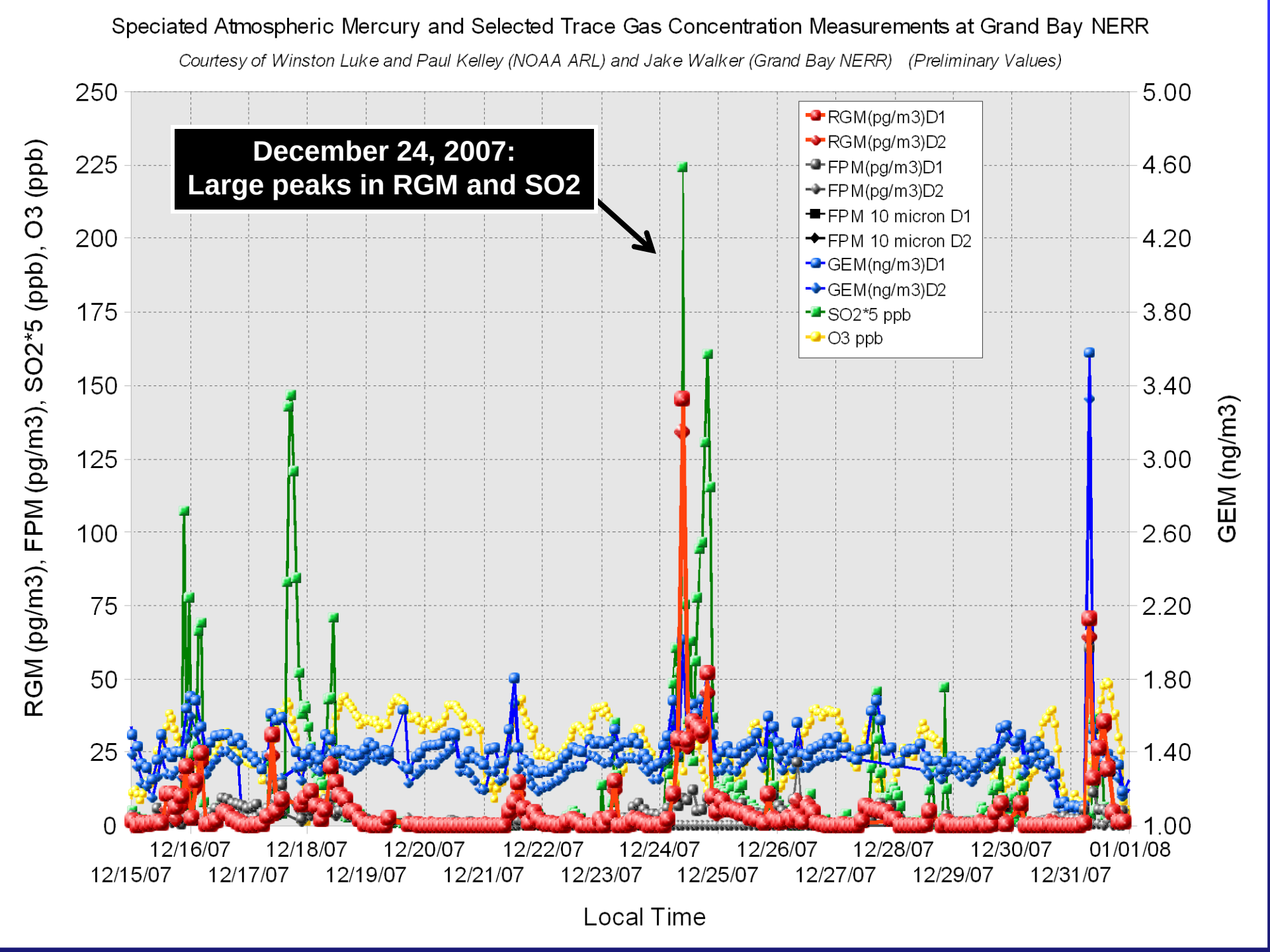
A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

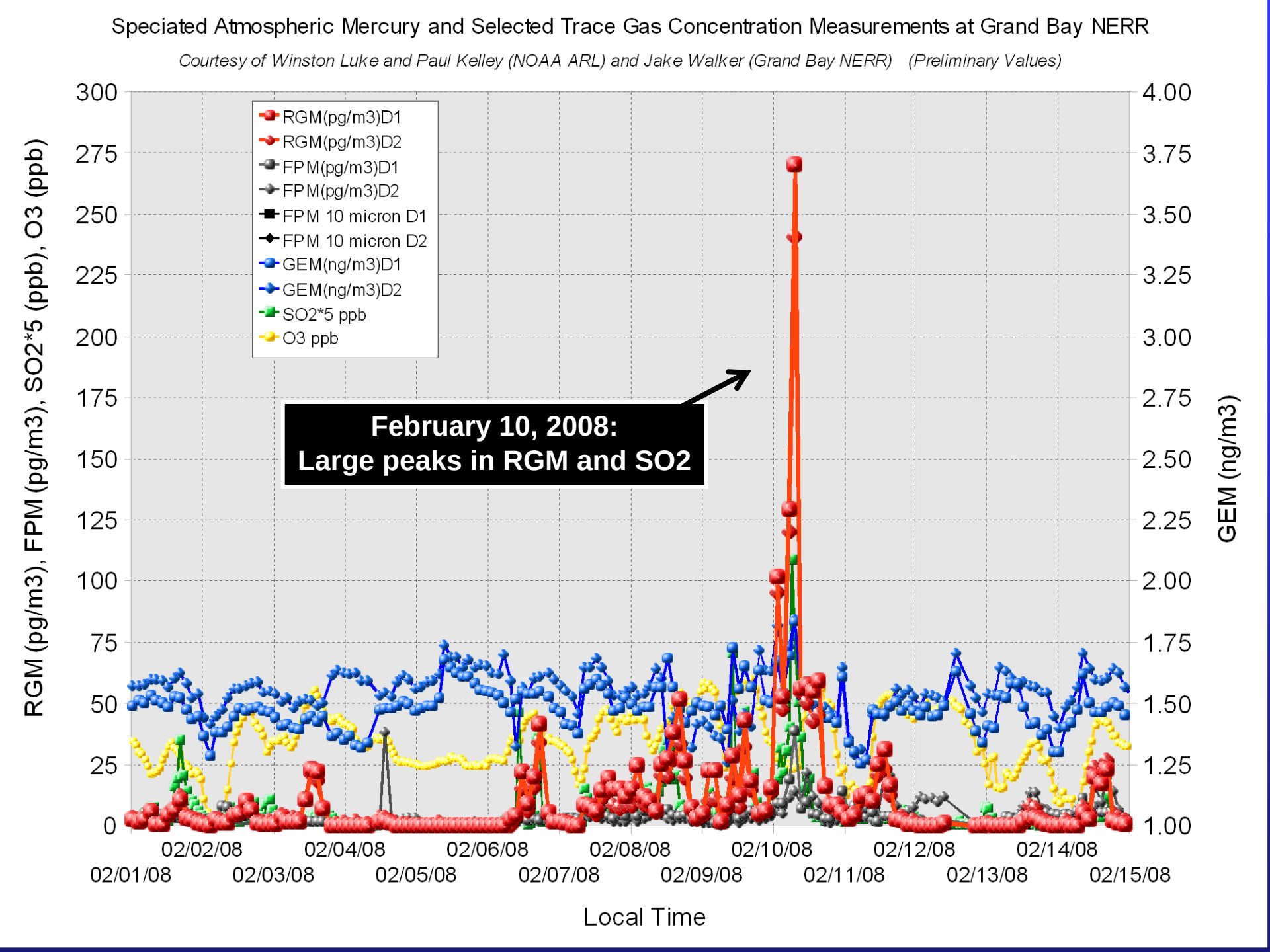

Hg(0)
Hg(II)
Hg(p)
Hg from other sources: local, regional & more distant
Hg(0)
Hg(II)
Hg(p)
Hg(0)
Hg(II)
Hg(p)
Hg(0)
Hg(II)
Hg(p)
Hg(0)
Hg(II)
Hg(p)
Measurement of wet deposition
Measurement of ambient air concentrations

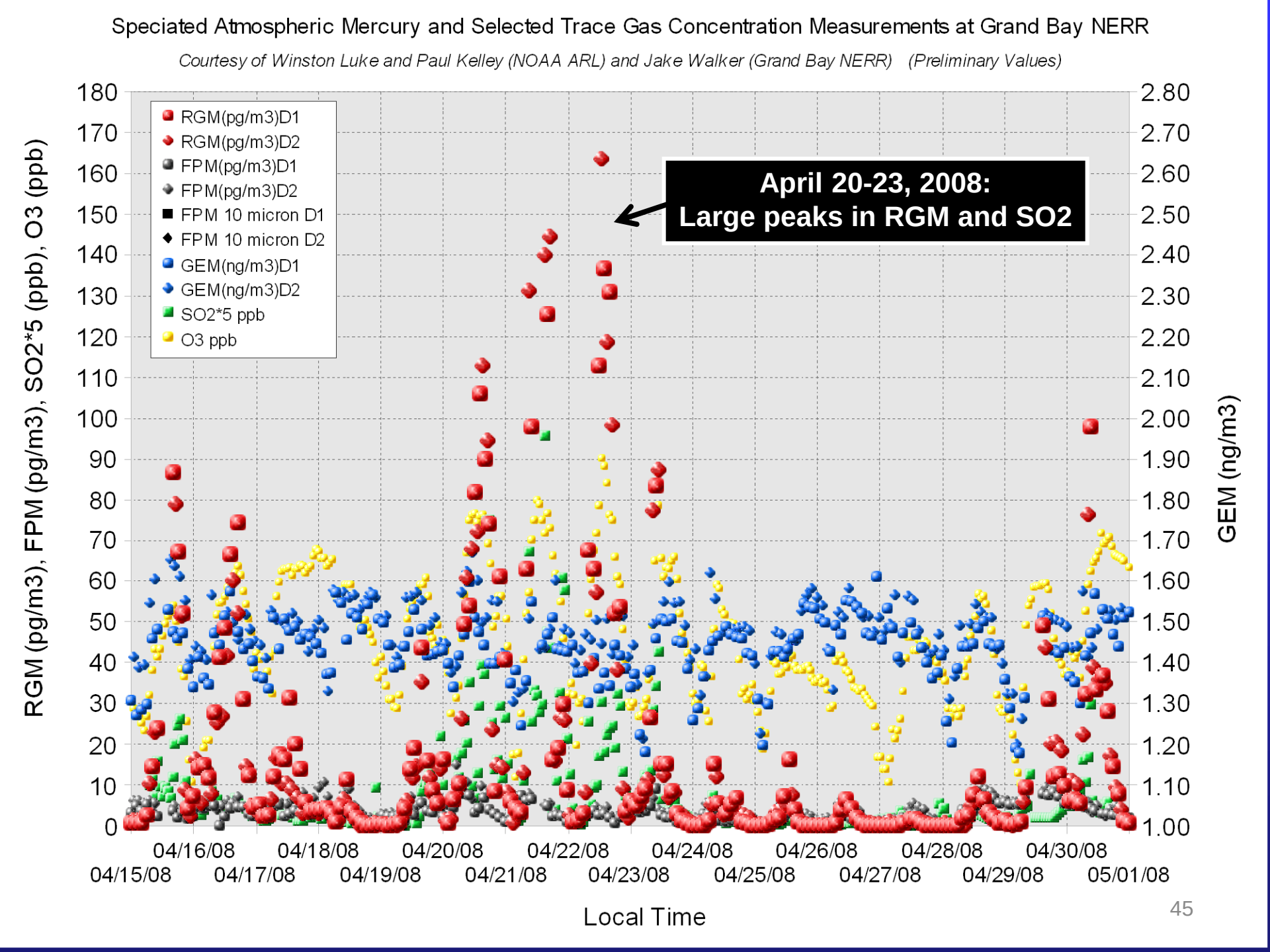
Speciated Atmospheric Mercury and Selected Trace Gas Concentration Measurements at Grand Bay NERR

Courtesy of Winston Luke and Paul Kelley (NOAA ARL) and Jake Walker (Grand Bay NERR) (Preliminary Values)




Speciated Atmospheric Mercury and Selected Trace Gas Concentration Measurements at Grand Bay NERR
Courtesy of Winston Luke and Paul Kelley (NOAA ARL) and Jake Walker (Grand Bay NERR) (Preliminary Values)
December 24, 2007:
Large peaks in RGM and SO2
RGM(pg/m3)D1
RGM(pg/m3)D2
FPM(pg/m3)D1
FPM(pg/m3)D2
FPM 10 micron D1
FPM 10 micron D2
GEM(ng/m3)D1
GEM(ng/m3)D2
SO2*5 ppb
O3 ppb
RGM (pg/m3), FPM (pg/m3), SO2*5 (ppb), O3 (ppb)
GEM (ng/m3)
250
225
200
175
150
125
100
75
50
25
0
5.00
4.60
4.20
3.80
3.40
3.00
2.60
2.20
1.80
1.40
1.00
12/15/07
12/16/07
12/17/07
12/18/07
12/19/07
12/20/07
12/21/07
12/22/07
12/23/07
12/24/07
12/25/07
12/26/07
12/27/07
12/28/07
12/29/07
12/30/07
12/31/07
01/01/08
Local Time


Speciated Atmospheric Mercury and Selected Trace Gas Concentration Measurements at Grand Bay NERR
Courtesy of Winston Luke and Paul Kelley (NOAA ARL) and Jake Walker (Grand Bay NERR) (Preliminary Values)
RGM(pg/m3)D1
RGM(pg/m3)D2
FPM(pg/m3)D1
FPM(pg/m3)D2
FPM 10 micron D1
FPM 10 micron D2
GEM(ng/m3)D1
GEM(ng/m3)D2
SO2*5 ppb
O3 ppb
February 10, 2008:
Large peaks in RGM and SO2
RGM (pg/m3), FPM (pg/m3), SO2*5 (ppb), O3 (ppb)
GEM (ng/m3)
300
275
250
225
200
175
150
125
100
75
50
25
0
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
02/01/08
02/02/08
02/03/08
02/04/08
02/05/08
02/06/08
02/07/08
02/08/08
02/09/08
02/10/08
02/11/08
02/12/08
02/13/08
02/14/08
02/15/08
Local Time

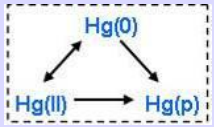

Speciated Atmospheric Mercury and Selected Trace Gas Concentration Measurements at Grand Bay NERR
Courtesy of Winston Luke and Paul Kelley (NOAA ARL) and Jake Walker (Grand Bay NERR) (Preliminary Values)
RGM(pg/m3)D1
RGM(pg/m3)D2
FPM(pg/m3)D1
FPM(pg/m3)D2
FPM 10 micron D1
FPM 10 micron D2
GEM(ng/m3)D1
GEM(ng/m3)D2
SO2*5 ppb
O3 ppb
April 20-23, 2008:
Large peaks in RGM and SO2
RGM (pg/m3), FPM (pg/m3), SO2*5 (ppb), O3 (ppb)
GEM (ng/m3)
Local Time
04/15/08
04/16/08
04/17/08
04/18/08
04/19/08
04/20/08
04/21/08
04/22/08
04/23/08
04/24/08
04/25/08
04/26/08
04/27/08
04/28/08
04/29/08
04/30/08
05/01/08

1. Measurements

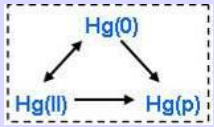
A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

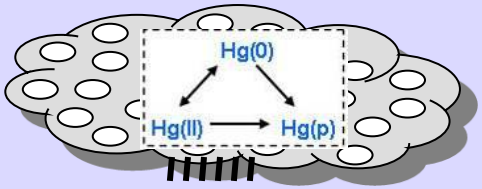
2. Modeling

A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project



Hg from other sources: local, regional & more distant





atmospheric deposition to the water surface

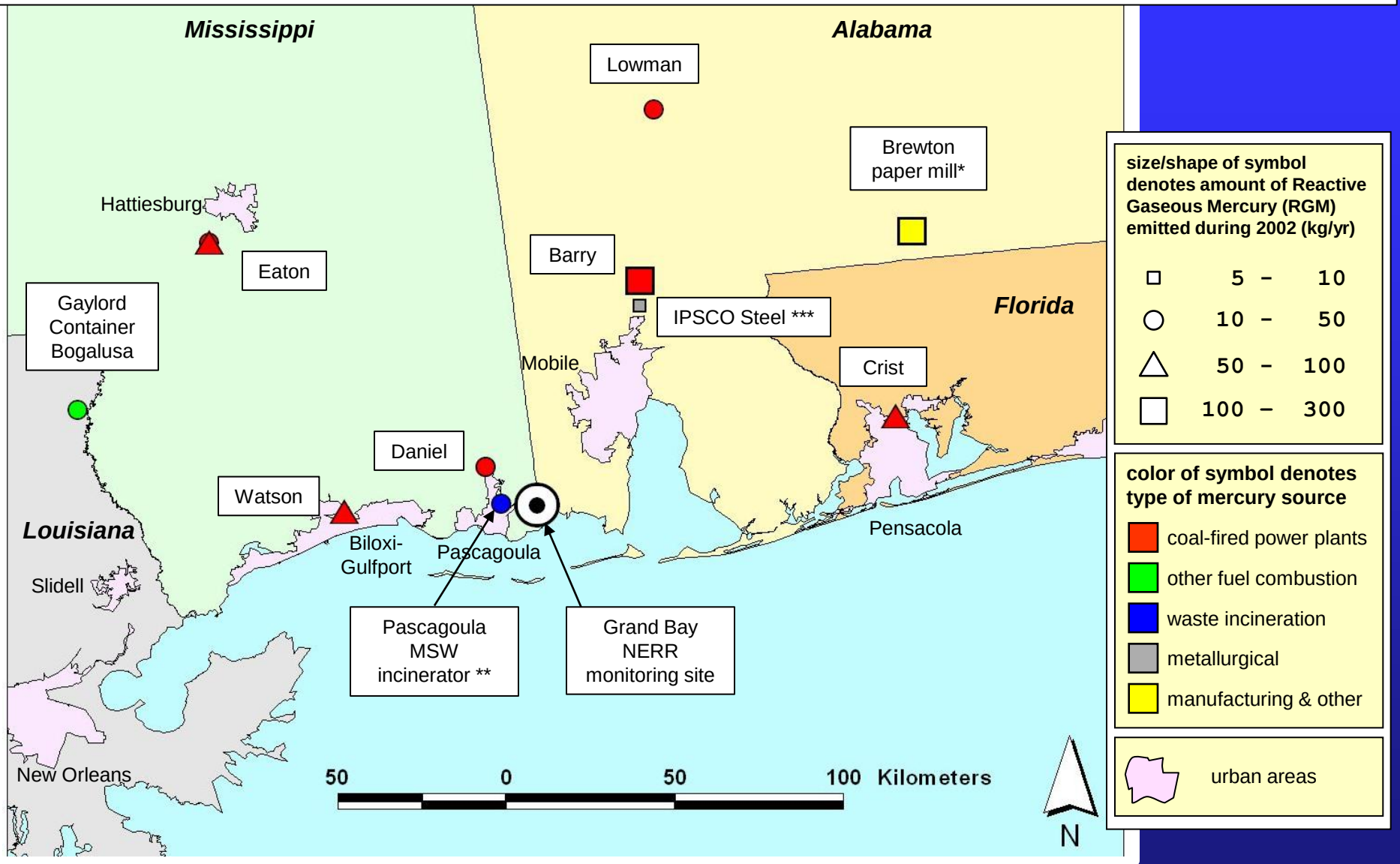
atmospheric deposition to the watershed

Measurement of wet deposition

Measurement of ambient air concentrations

An essential factor in carrying out a meaningful model evaluation in cases where local/regional sources may be important is to have <u>accurate emissions data</u> for local/regional sources, valid for the time of the episode being studied

Grand Bay NERR sampling site, with large point sources of Reactive Gaseous Mercury in the region, based on the EPA's 2002 National Emissions Inventory

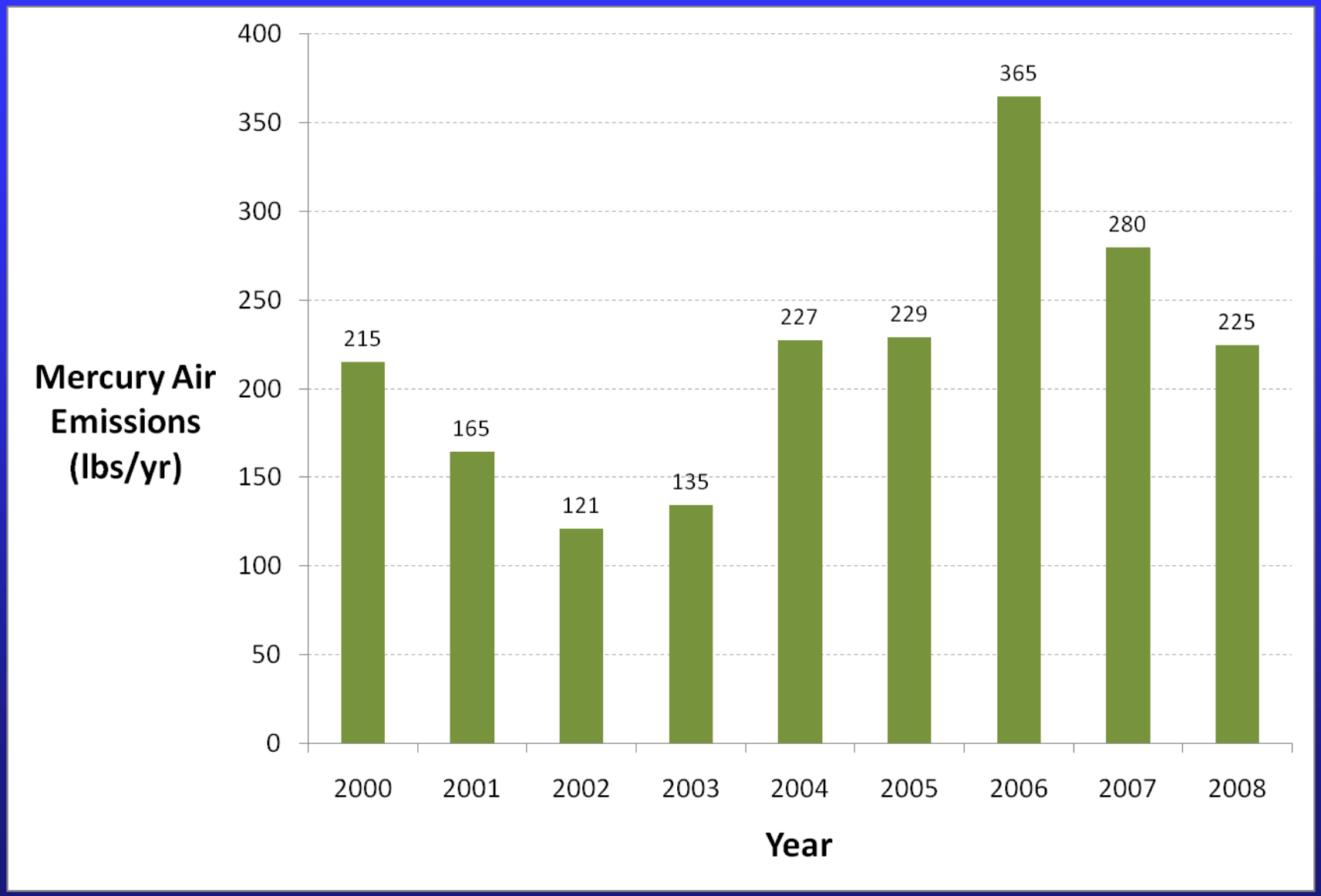


* Brewton paper mill mercury emissions included in 2002 NEI , but do not appear to be in 2000-2008 TRI

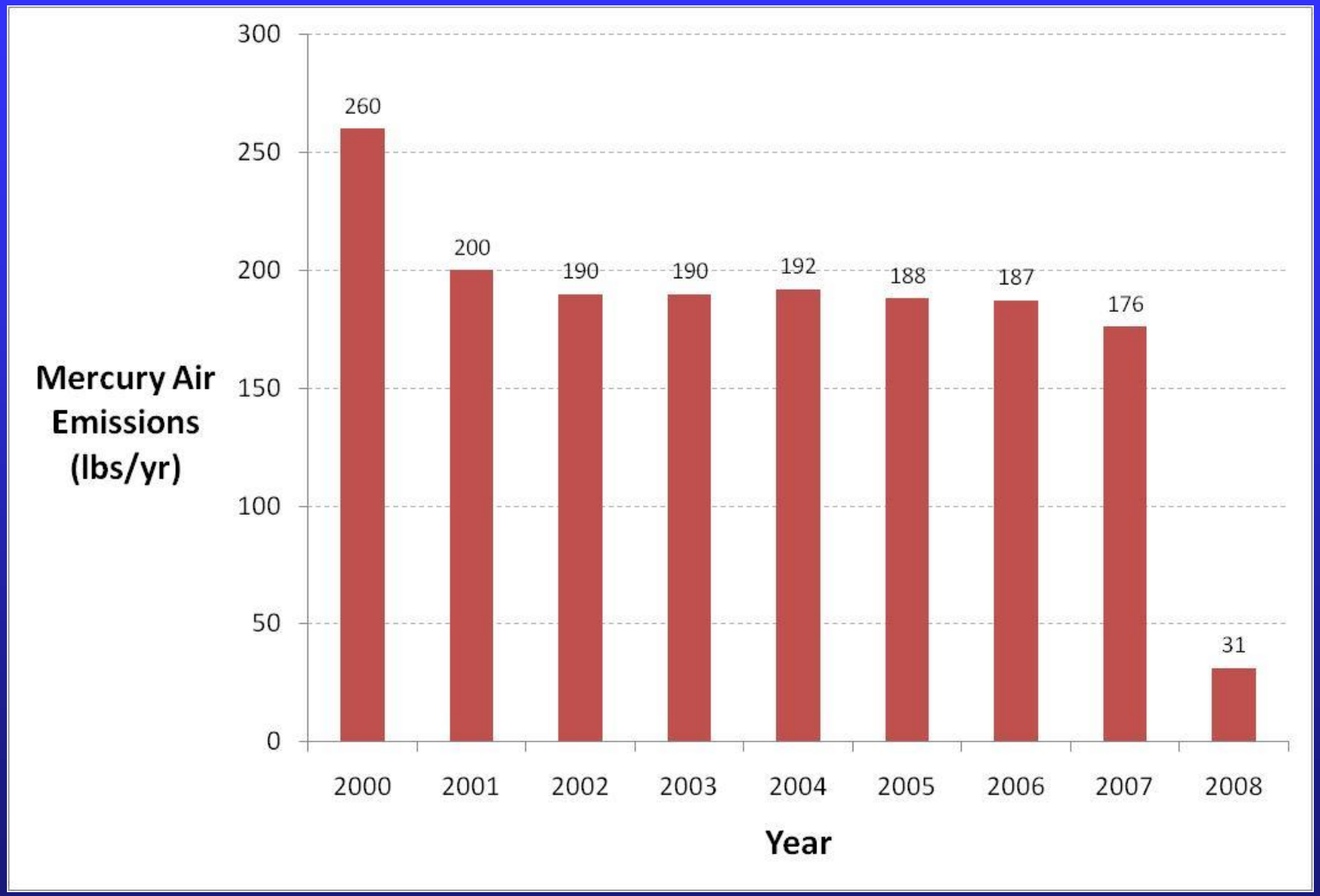
** Pascagoula MSW incinerator mercury emissions included in 2002 NEI but incineration ceased in Jan 2001

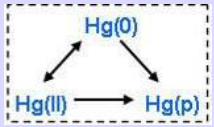
*** Ipsco Steel had significant mercury emissions in 2002 NEI, but negligible emissions reported in 2008 TRI

Mercury Air Emissions from the Victor J. Daniel Power Plant as reported to the Toxic Release Inventory

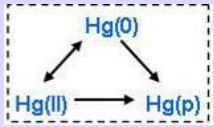


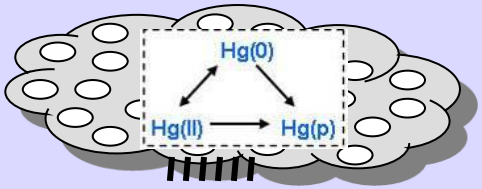
Mercury Air Emissions from Charles R. Lowman Power Plant as reported to the Toxic Release Inventory

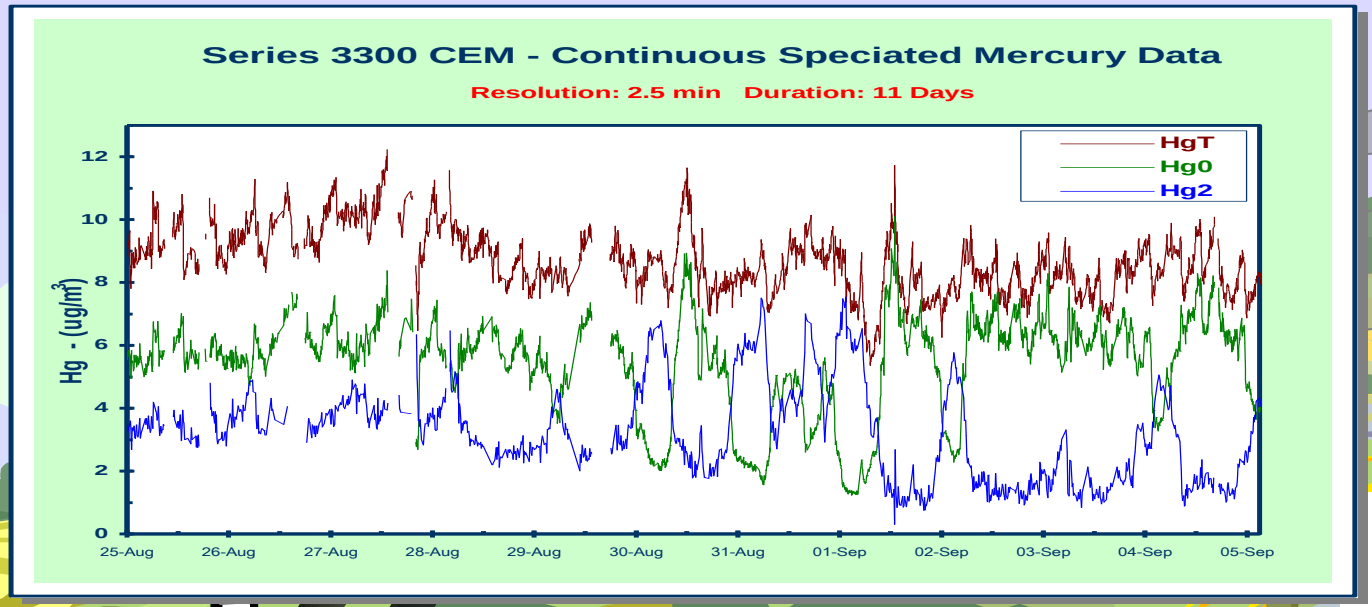




Hg from other sources: local, regional & more distant



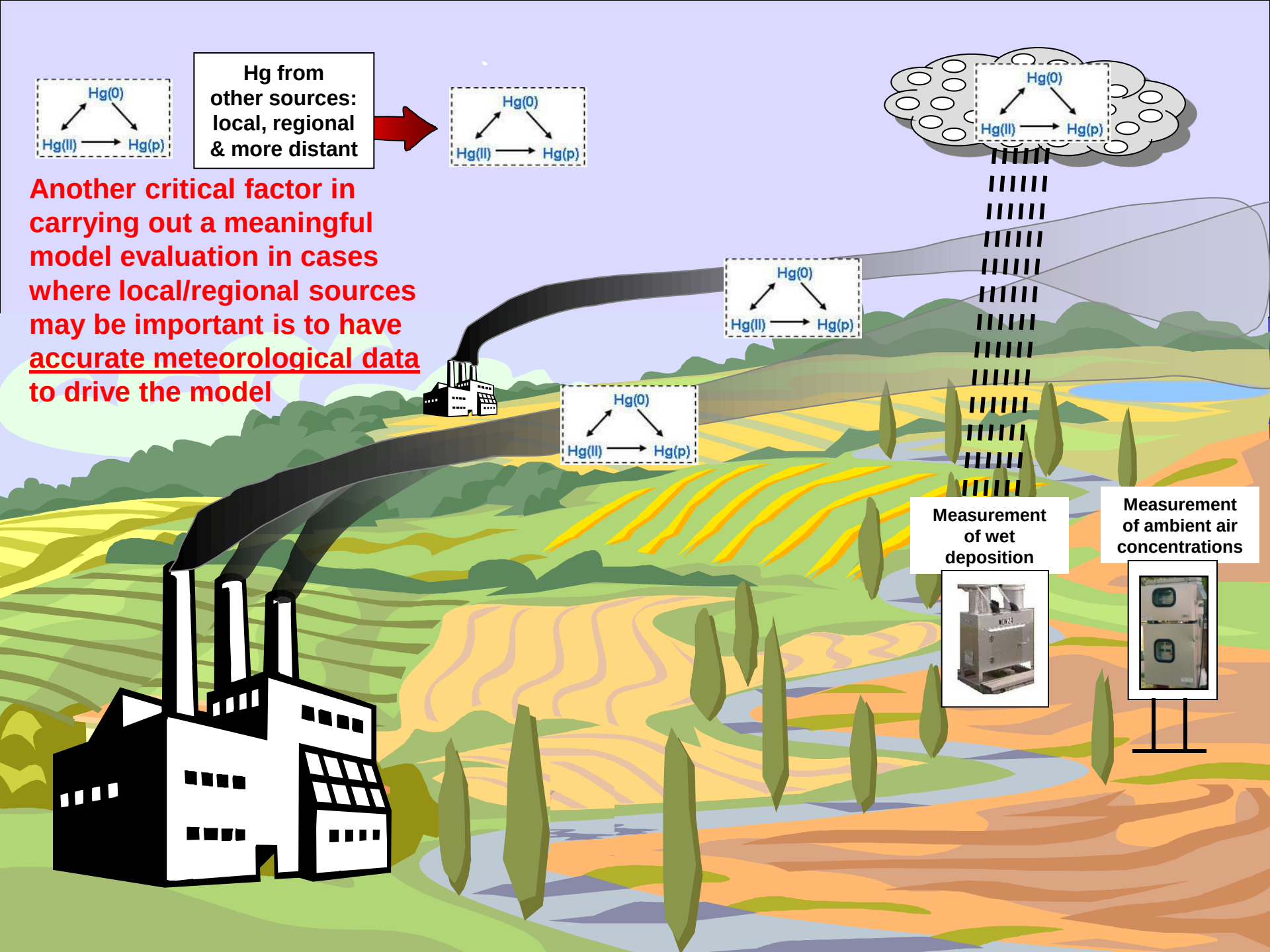




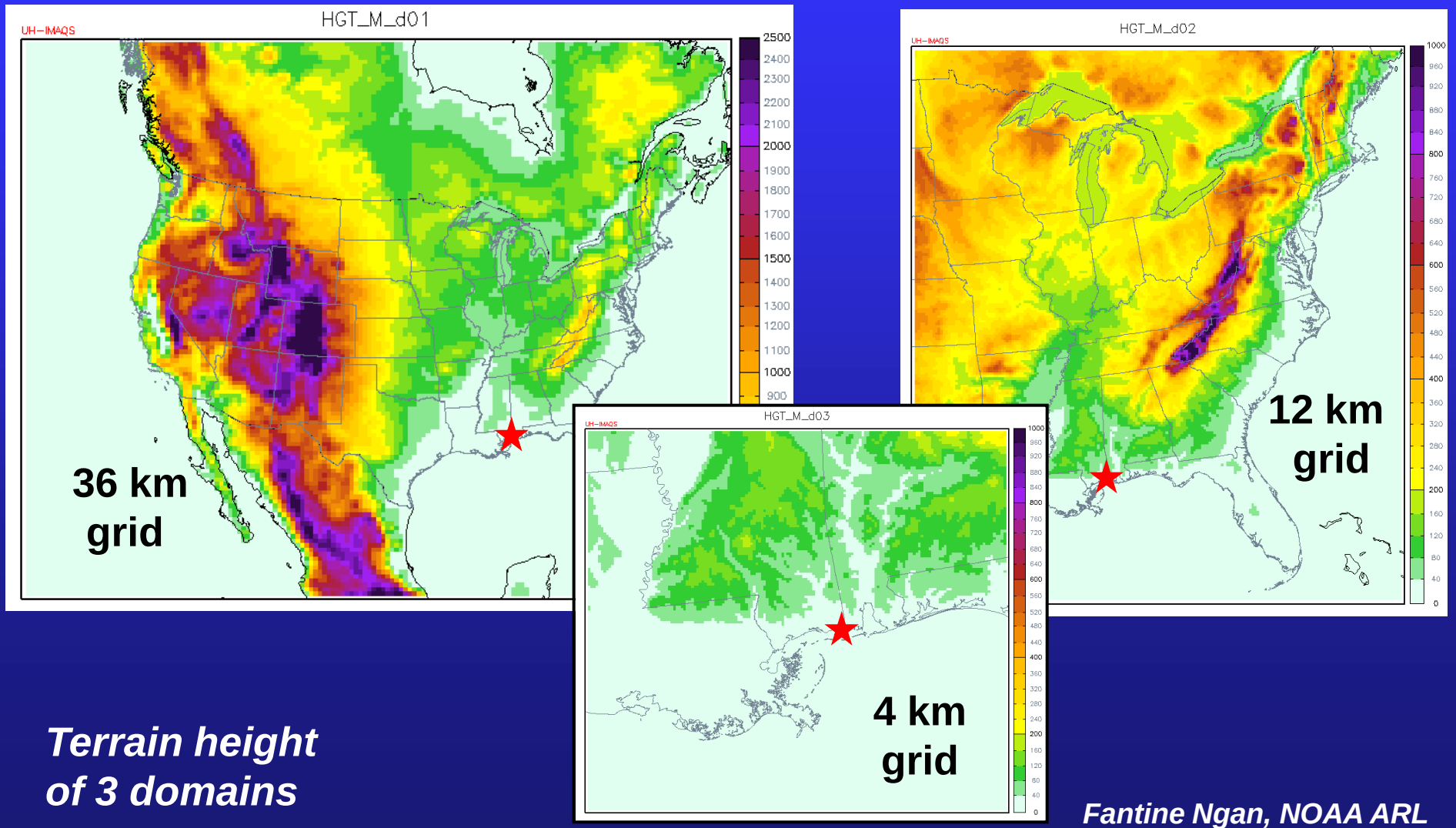
atmospheric deposition to the water surface

Measurement of wet deposition

Measurement of ambient air concentrations


Hg(0)
Hg(II)
Hg(p)
Hg from other sources: local, regional & more distant
Hg(0)
Hg(II)
Hg(p)
Hg(0)
Hg(II)
Hg(p)
Another critical factor in carrying out a meaningful model evaluation in cases where local/regional sources may be important is to have accurate meteorological data to drive the model
Hg(0)
Hg(II)
Hg(p)
Hg(0)
Hg(II)
Hg(p)
Measurement of wet deposition
Measurement of ambient air concentrations

High-resolution meteorological simulations being carried out for episodes at the Grand Bay NERR [★] by Dr. Fantine Ngan, a post-doc at NOAA ARL, and independently by Dr. Rao Dodla of Jackson State University



Terrain height of 3 domains

Fantine Ngan, NOAA ARL

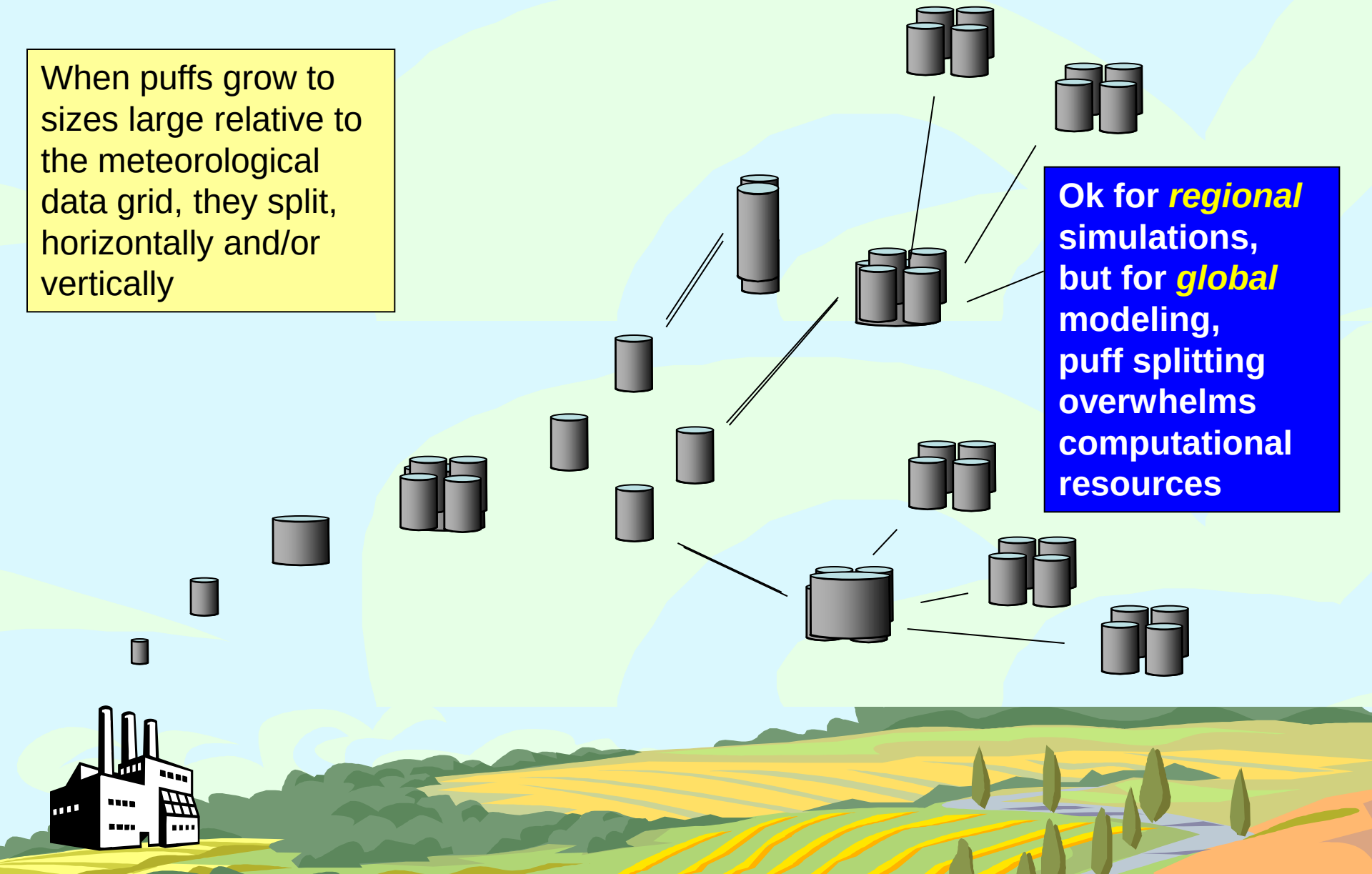
1. Measurements

A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

2. Modeling

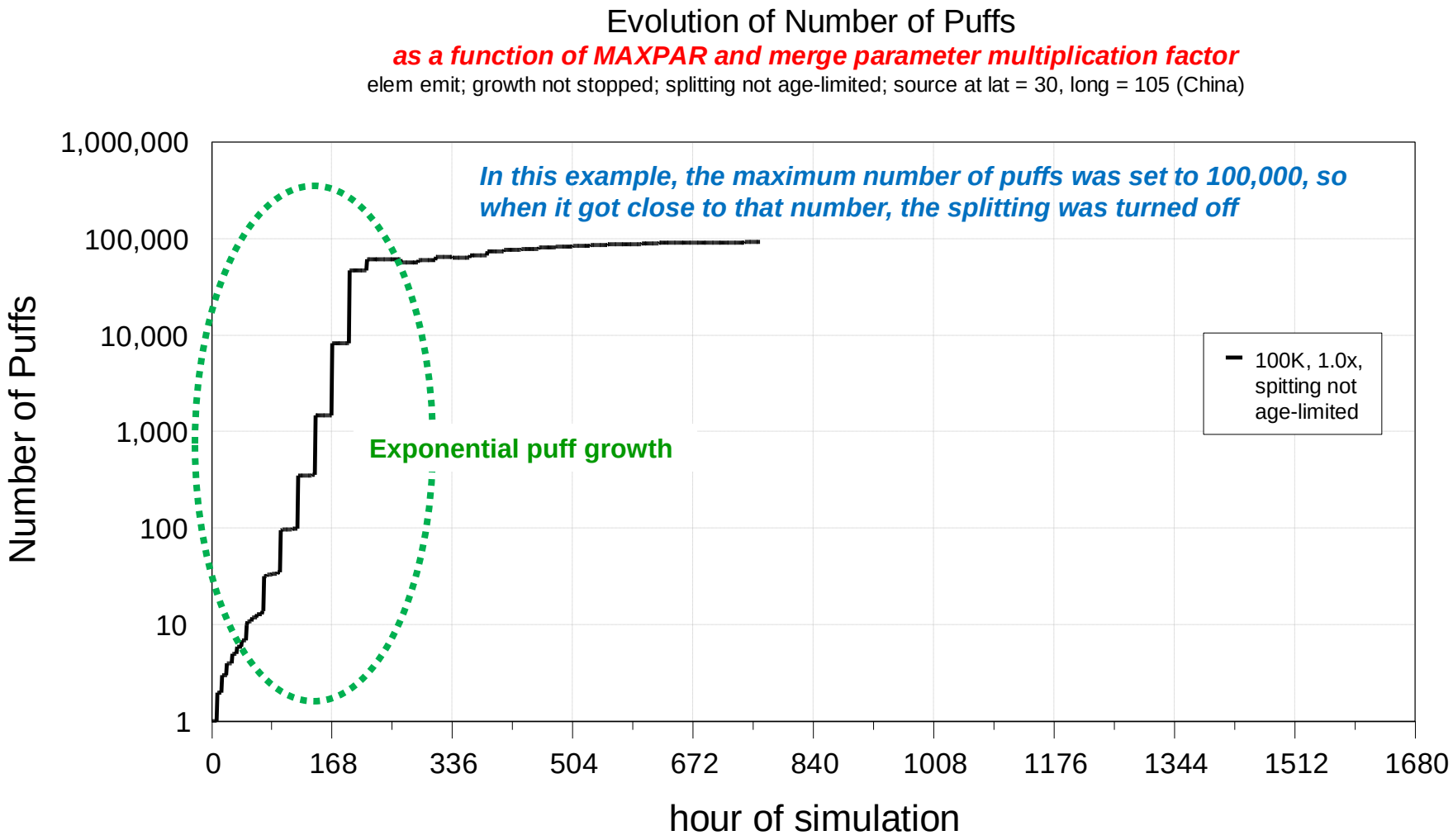
A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project

When puffs grow to sizes large relative to the meteorological data grid, they split, horizontally and/or vertically

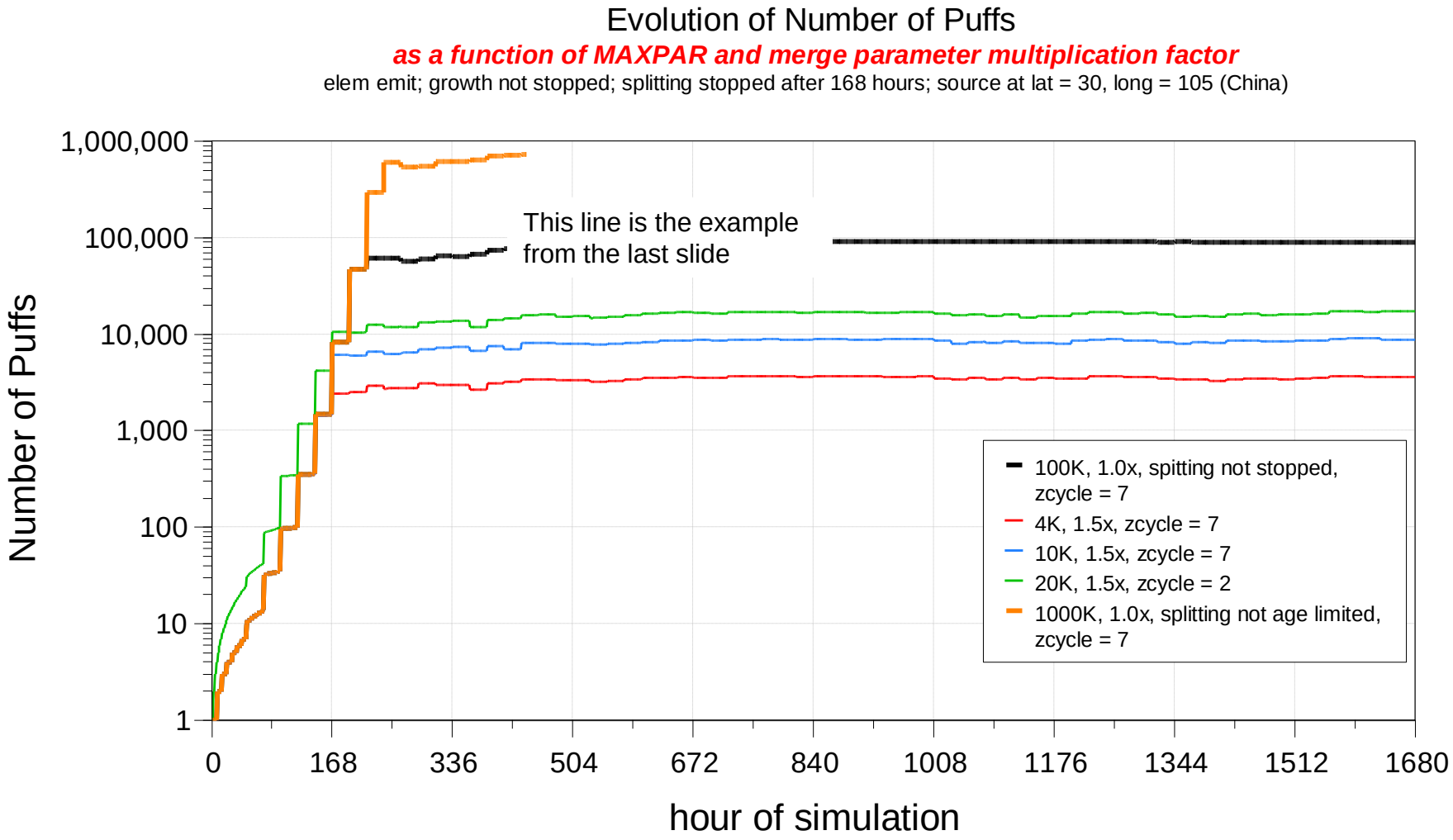


Ok for *regional* simulations, but for *global* modeling, puff splitting overwhelms computational resources

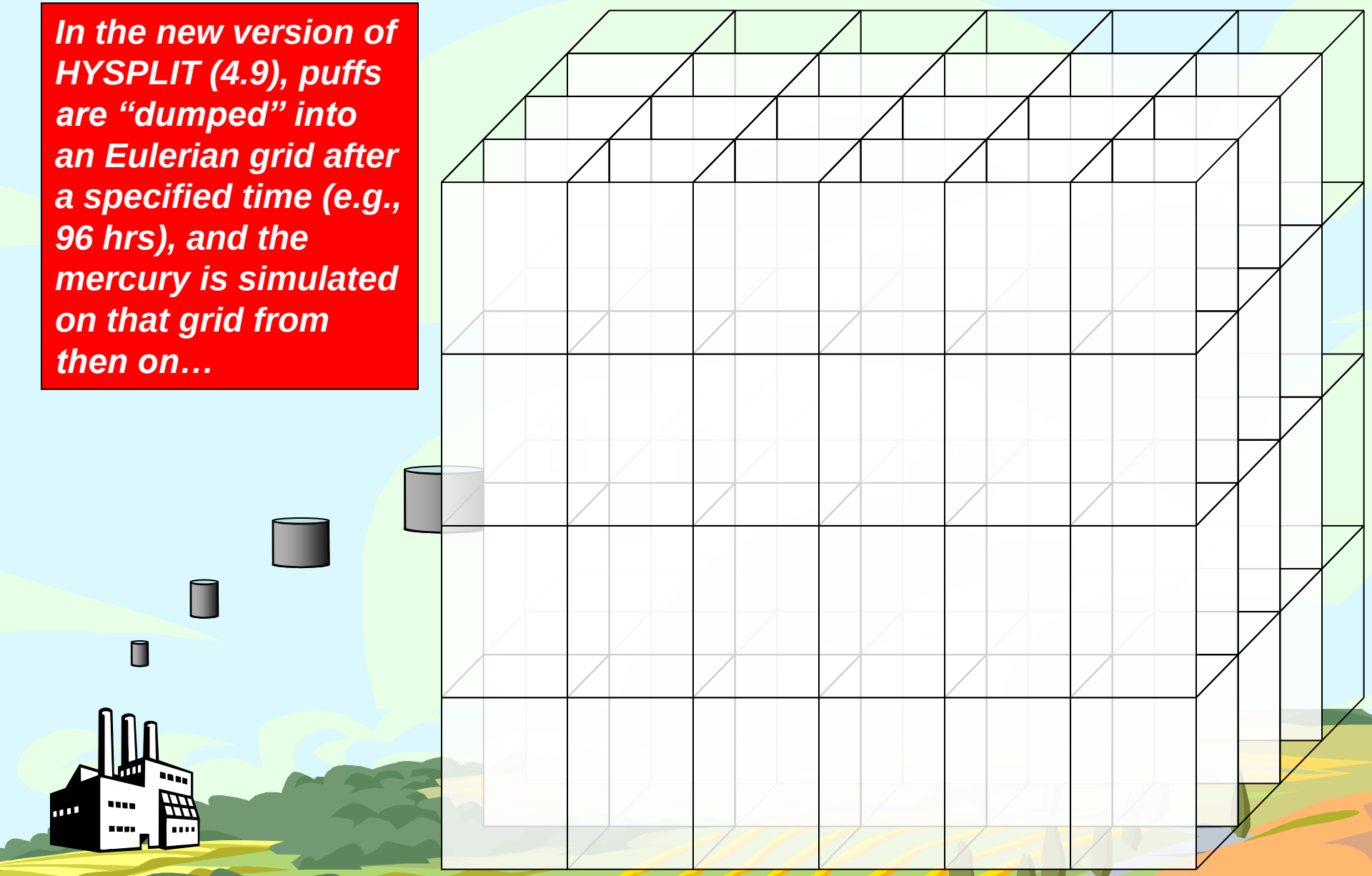
Due to puff splitting, the number of puffs quickly overwhelms numerical resources



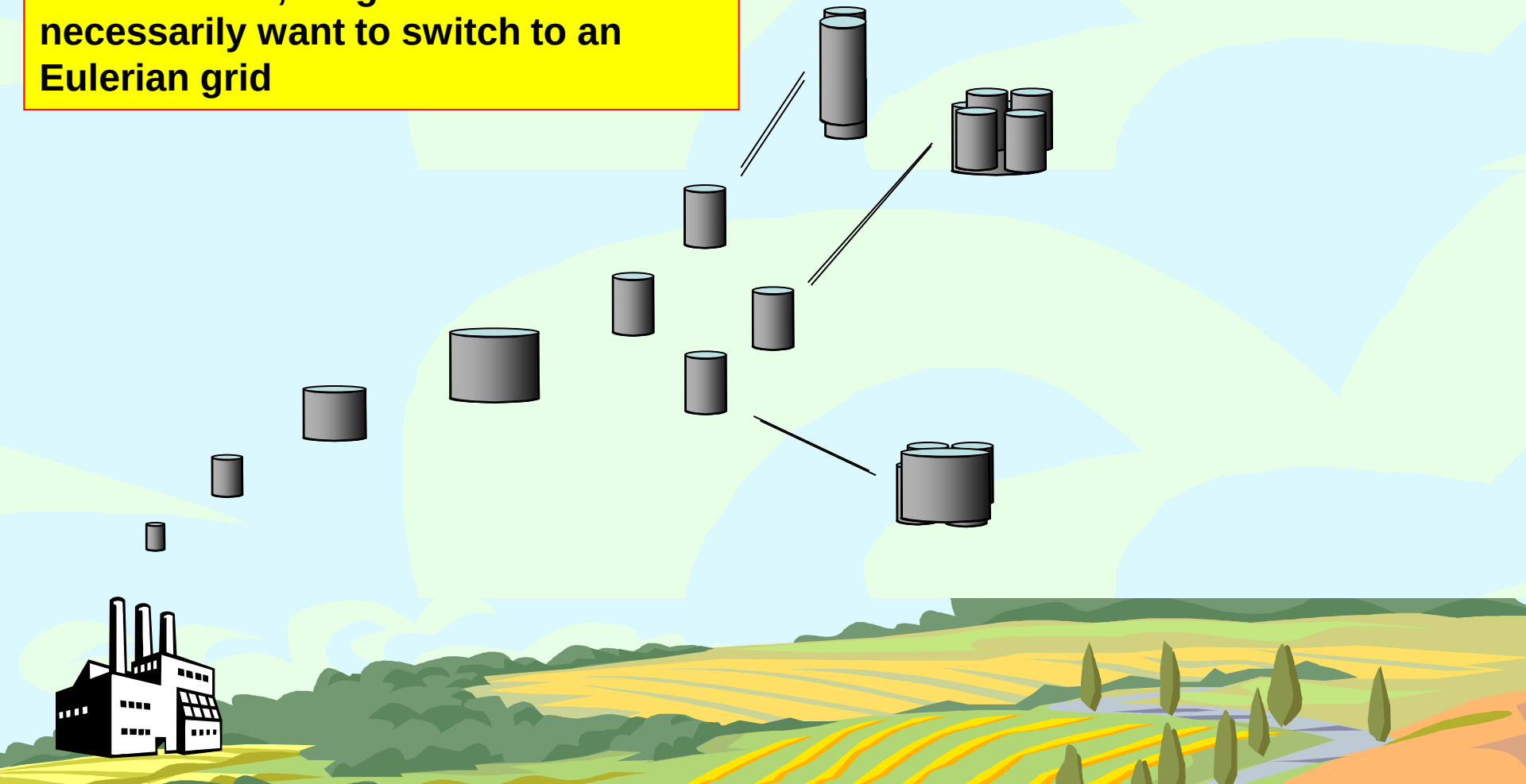
In each test, the number of puffs rises to the maximum allowable within ~ one week (and then splitting stops…)



In the new version of HYSPLIT (4.9), puffs are "dumped" into an Eulerian grid after a specified time (e.g., 96 hrs), and the mercury is simulated on that grid from then on…

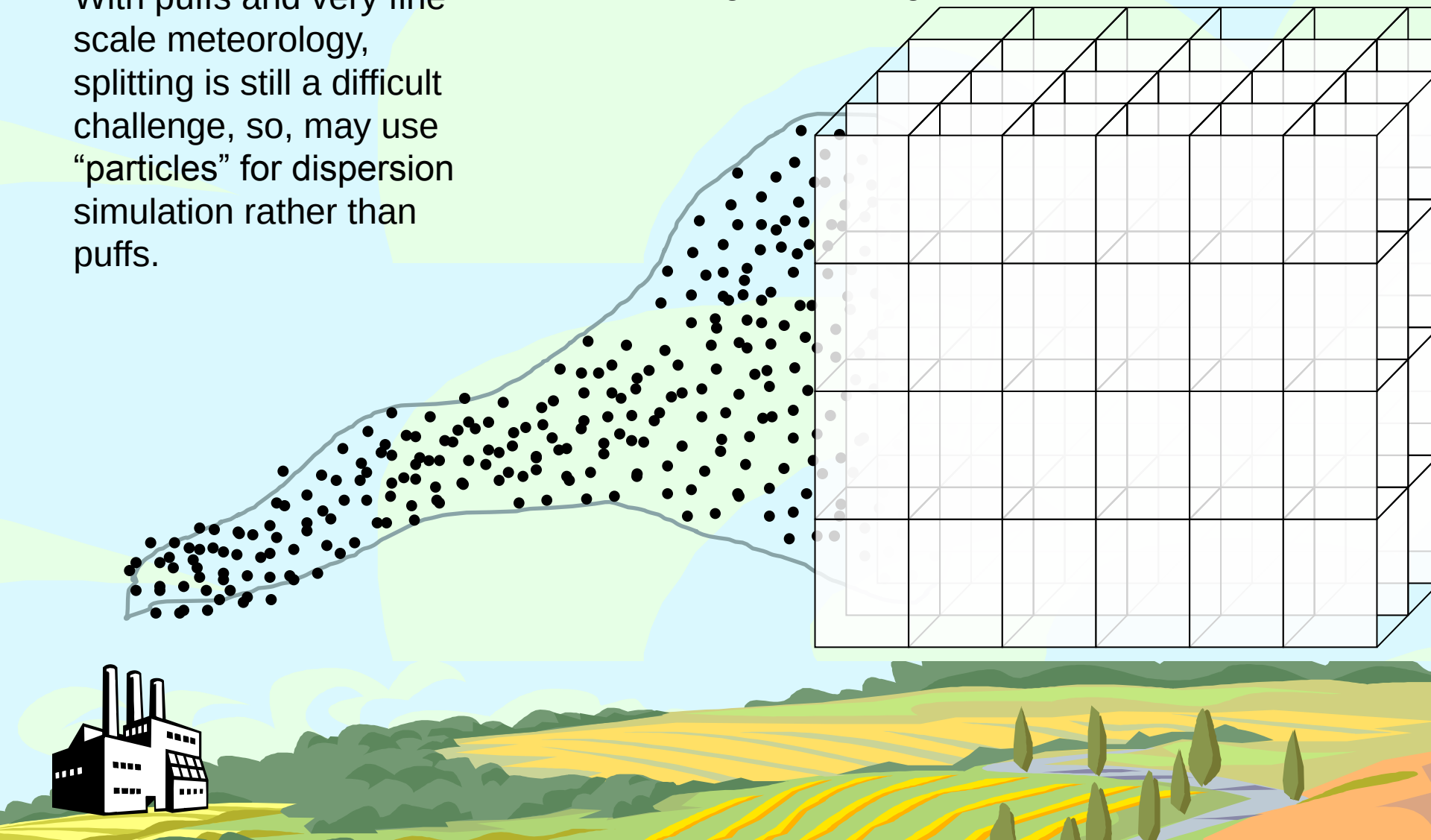


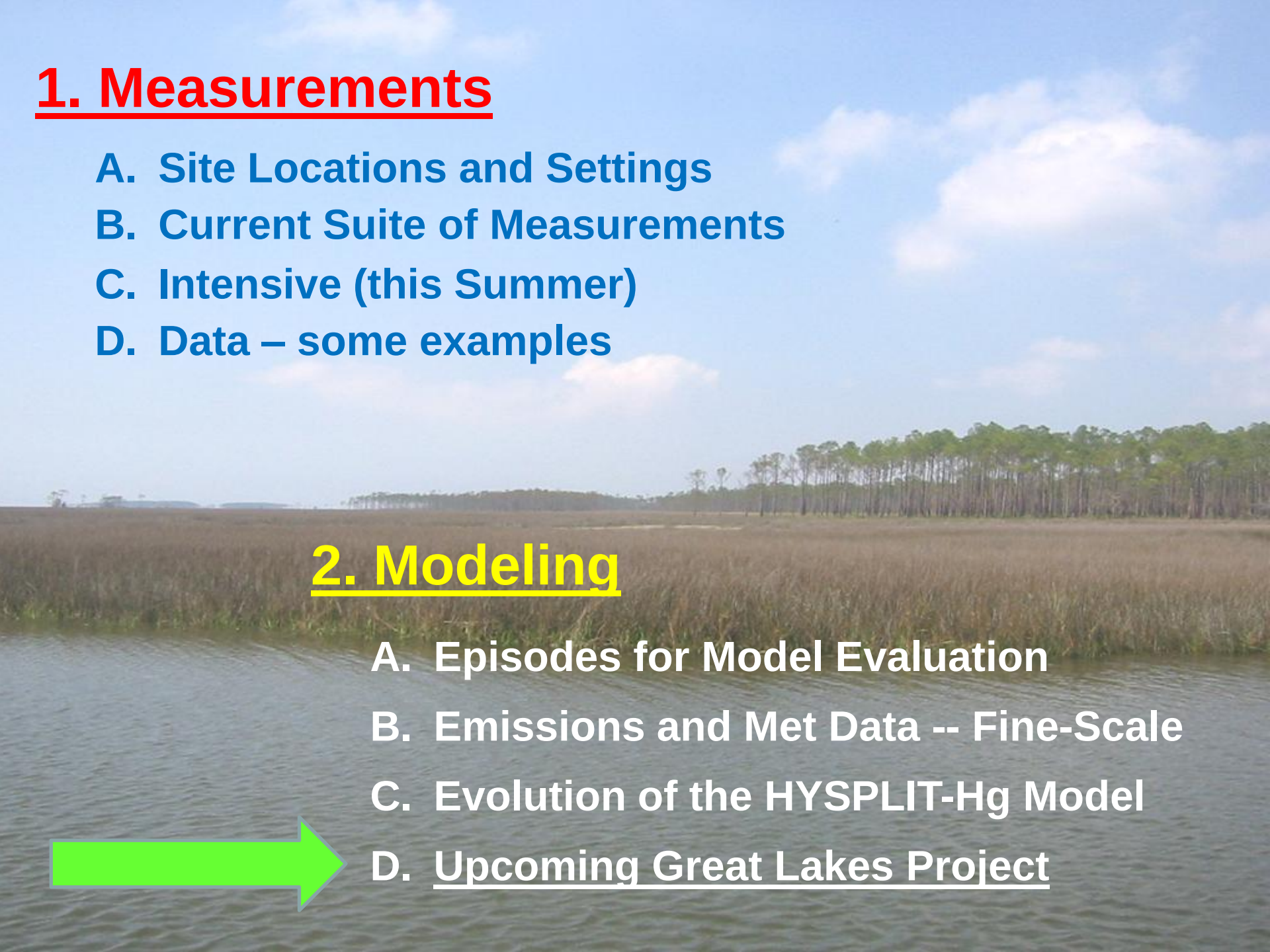
We are discovering that with puffs and very fine scale meteorology, splitting is still a difficult challenge in the near field, long before one would necessarily want to switch to an Eulerian grid



With puffs and very fine scale meteorology, splitting is still a difficult challenge, so, may use “particles” for dispersion simulation rather than puffs.

The particles would still be transferred to an Eulerian grid after a given time





1. Measurements

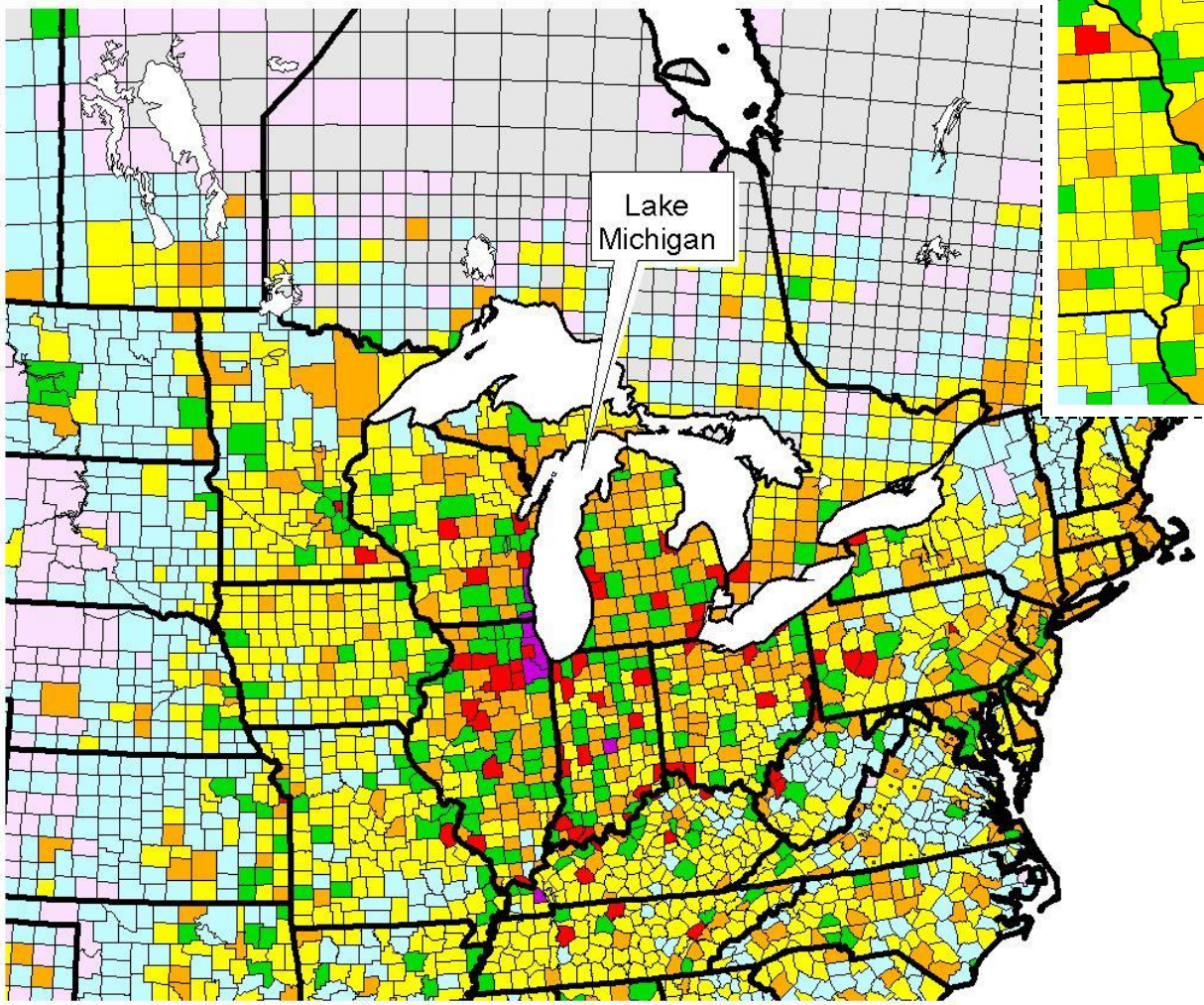
A. Site Locations and Settings
B. Current Suite of Measurements
C. Intensive (this Summer)
D. Data – some examples

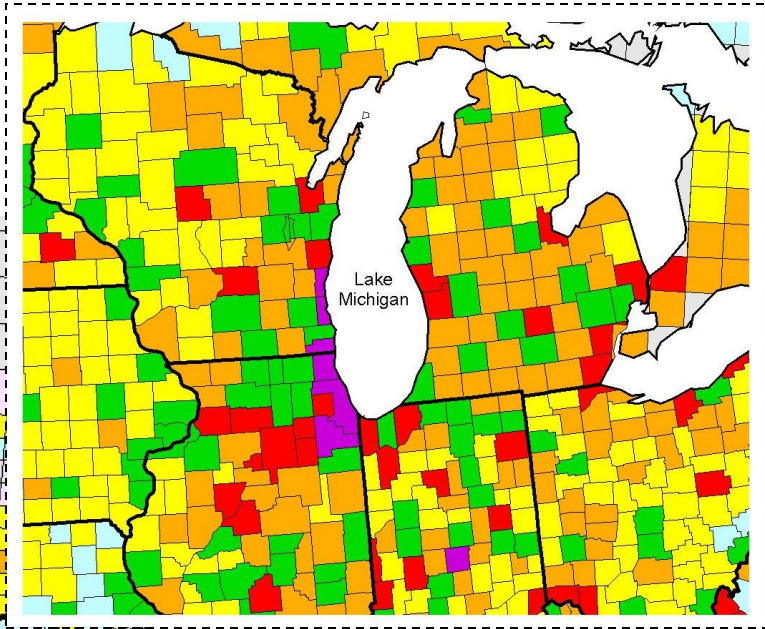
2. Modeling

A. Episodes for Model Evaluation
B. Emissions and Met Data -- Fine-Scale
C. Evolution of the HYSPLIT-Hg Model
D. Upcoming Great Lakes Project


Have done a lot of source-receptor modeling work for the Great Lakes.
New, expanded study of source attribution for atmospheric mercury deposition to the Great Lakes, as part of the
Great Lakes Restoration Initiative

Geographical Distribution of 1999 Direct Deposition Contributions to Lake Michigan

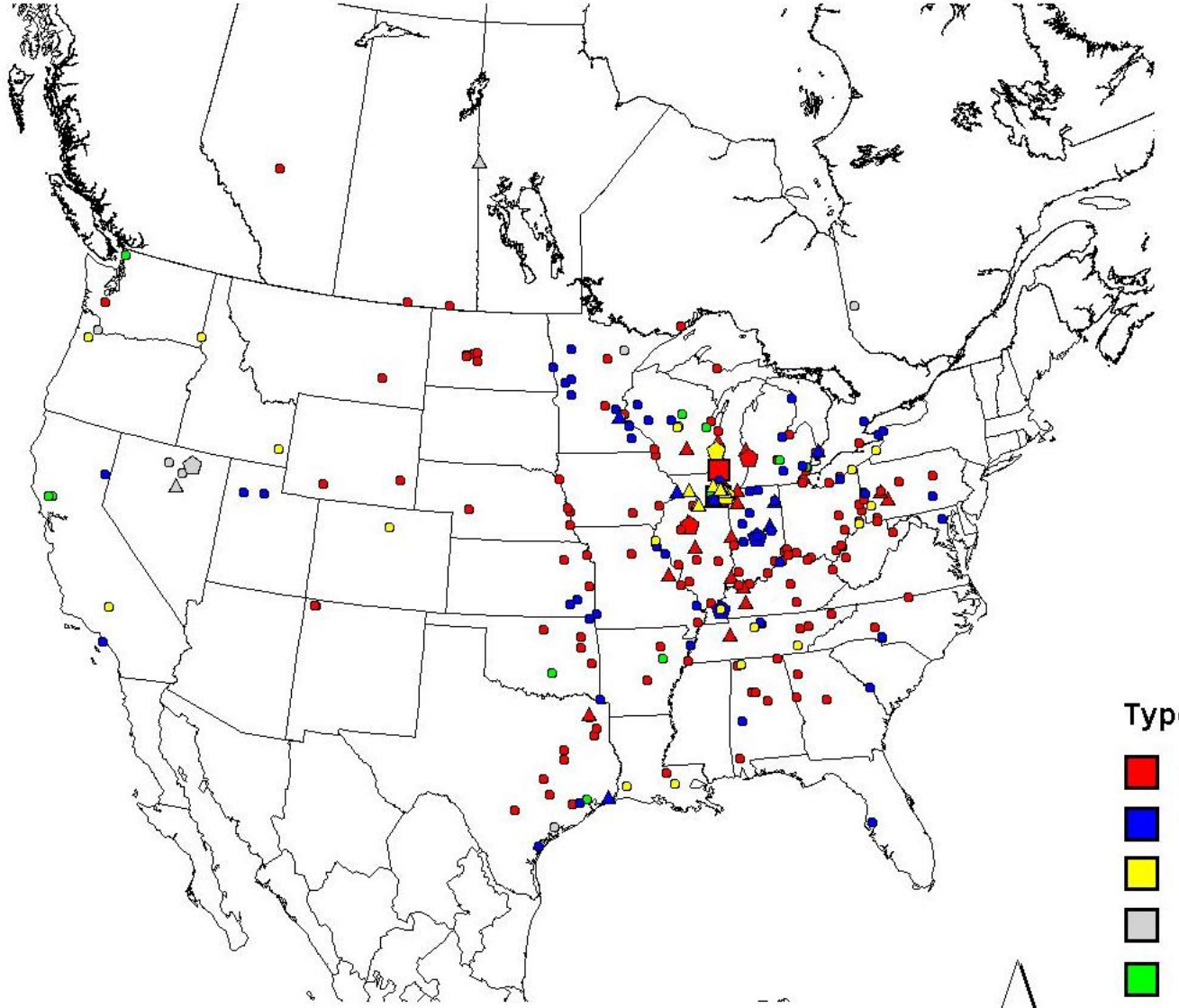




Deposition Contribution of Source Area to Receptor (ug deposited / year per km^2 of receptor area) per (km^2 of source area)

- 0 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- 1 - 10
- 10 - 100
- 100 - 1,000
- 1,000 - 10,000
- 10,000 - 100,000

Largest atmospheric deposition contributors to Lake Michigan based on 1999-2000 emissions



Fraction of total modeled deposition contributed by a particular source

- 0.1 - 0.3 %
- 0.3 - 1 %
- 1 - 3 %
- 3 - 10 %
- 10 - 30 %

Type of Emission Source

- coal-fired electricity generation
- waste incineration
- manufacturing
- metallurgical
- other fuel combustion

1000 0 1000 2000 Kilometers

N

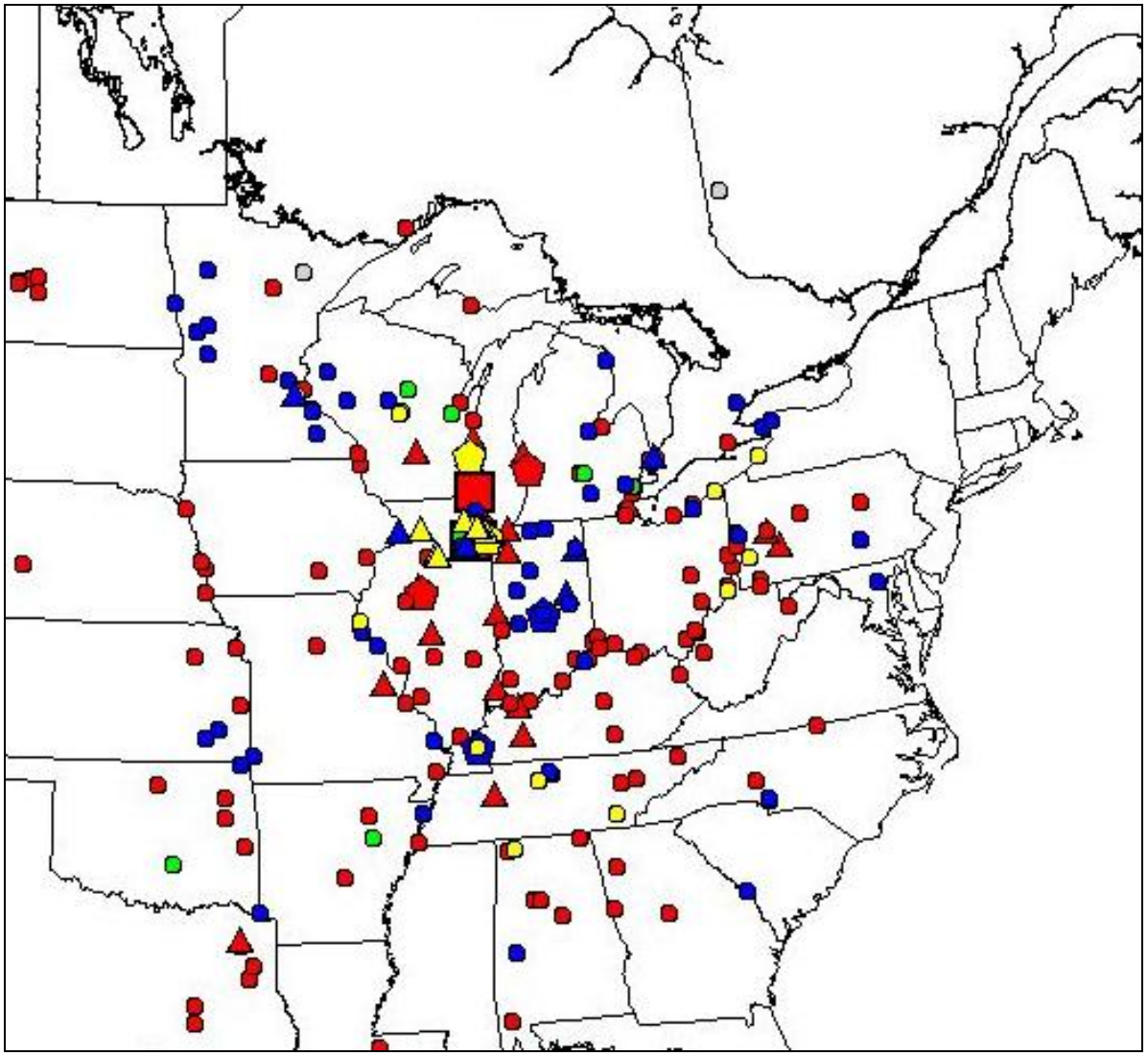
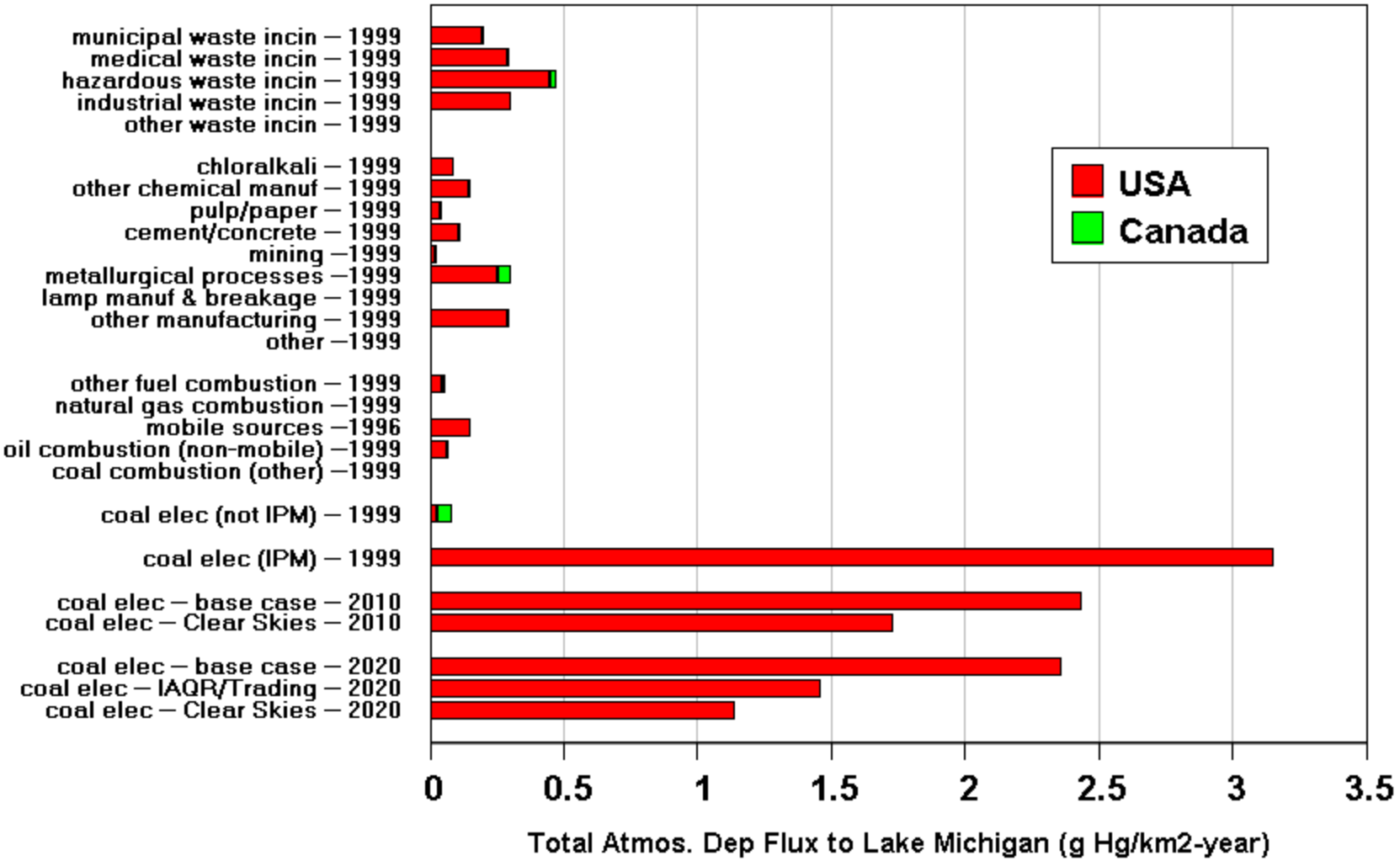
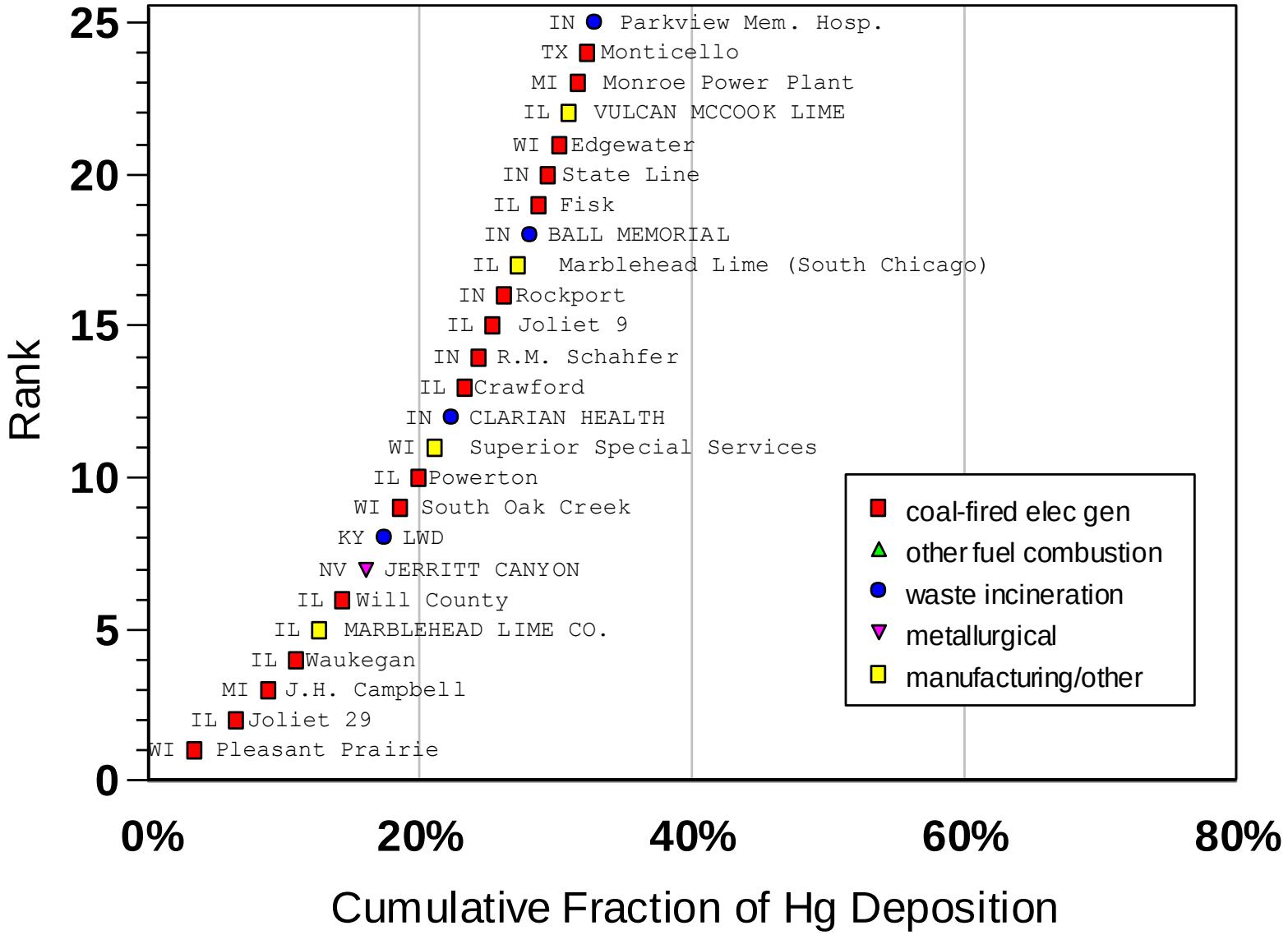


Figure 44. Largest modeled contributors to Lake Michigan (close-up).
(same legend as previous slide)

Atmospheric Deposition Flux to Lake Michigan from Anthropogenic Mercury Emissions Sources in the U.S. and Canada

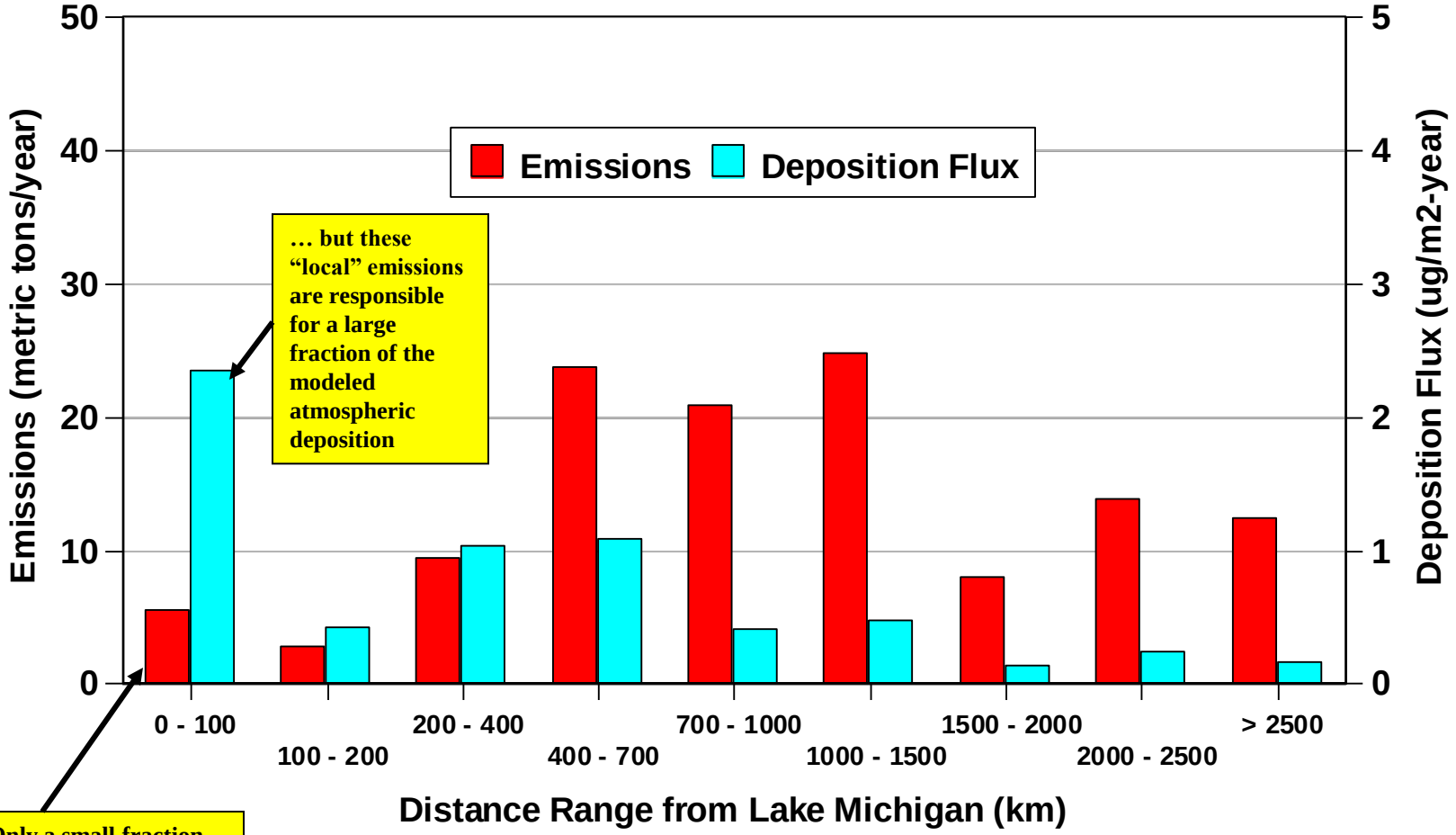


Top 25 modeled sources of atmospheric mercury to Lake Michigan (based on 1999 anthropogenic emissions in the U.S. and Canada)



Emissions and deposition to Lake Michigan arising from different distance ranges

(based on 1999 anthropogenic emissions in the U.S. and Canada)




Thanks!